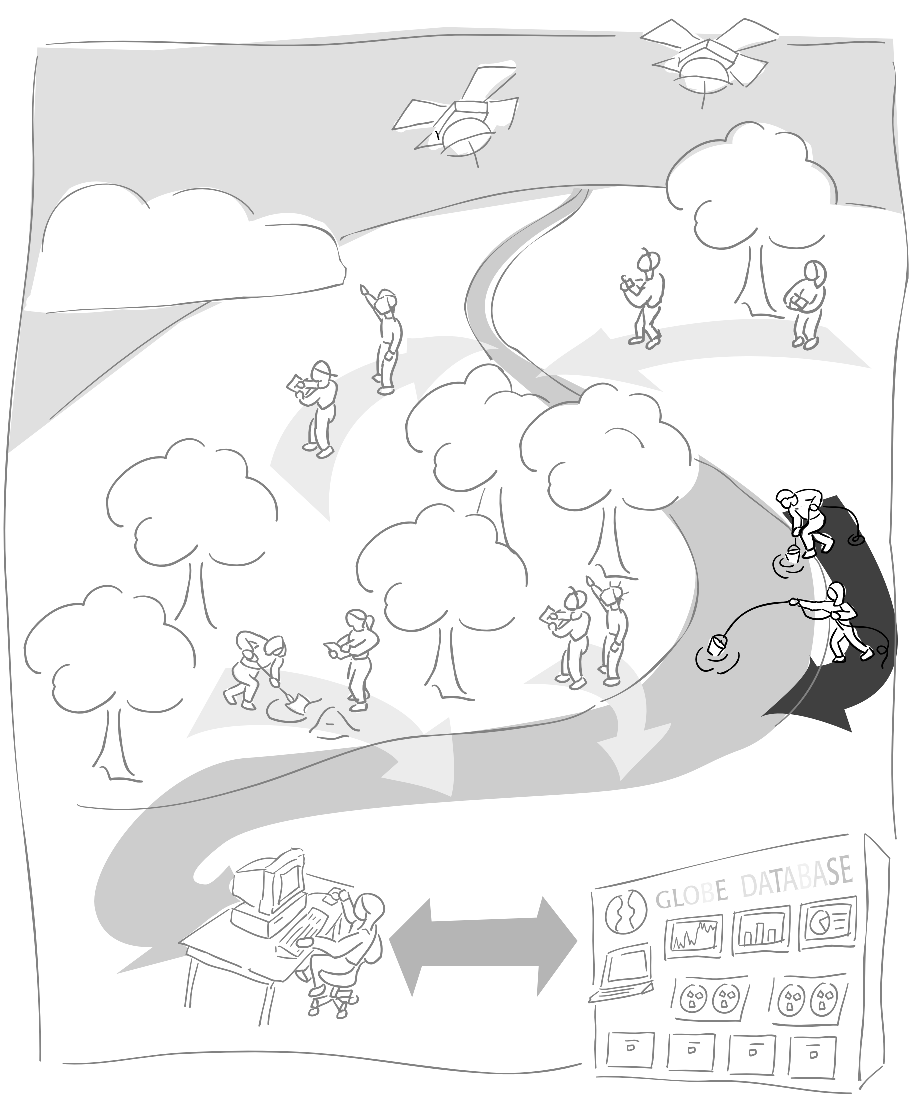
Hydrology Investigation



A GLOBE™ Learning Investigation

Hydrology Investigation at a Glance

Protocols

Weekly Measurements:

Transparency
Water Temperature
Dissolved Oxygen
pH
Electrical Conductivity
Salinity
Alkalinity
Nitrate

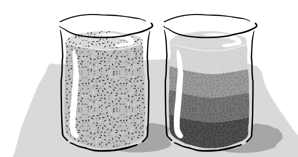
Suggested Sequence of Activities

Read the scientists' letter before you head out into the field.

Water Walk sets the stage for developing interest in water quality/chemistry.

Model Your Watershed provides the big picture view of students' watershed and the water study site in relation to this watershed.

Practicing the Protocols guides students through learning how to use the instruments and following the protocols so they collect reliable data.



Begin Field Sampling: your class goes to its site and begins the weekly measurements for water.

Focus on Key Science Ideas by performing the following Learning Activities:

Water Detectives and *The pH Game* introduce students to key water chemistry variables and to the need for instrumentation to make certain measurements.

Water, Water Everywhere! How Does it Compare? shows students how to analyze trends in their data and compare their data to other schools' data. This activity should be ongoing and repeated regularly as the data accumulates.

Modeling Your Water Balance lets students explore how to use their data for modeling.

Macroinvertebrate Discovery explores the connection between water measurements and aquatic life. This activity could be ongoing and repeated as conditions change.

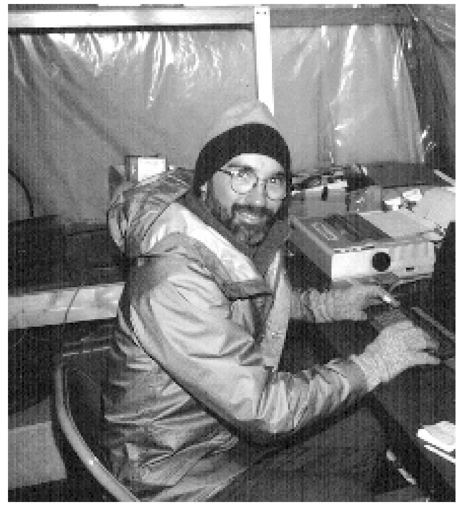
Start linking water data to other GLOBE data.

Table of Contents

Appendix

Duplicate and distribute to students.

Scientists' Letter to Students



Dear GLOBE Students,

We are the principal scientists on the GLOBE Hydrology and Water Chemistry investigation, and we welcome you to the program. You are participating in a scientific program that addresses a critical gap in our knowledge about the Earth.

Hydrology is the study of water, one of the most critical resources on Earth. Water is essential to all life. You and your fellow students in schools around the world will collect what should be the broadest set of measurements on water quality compiled to date. This GLOBE program will result in more bodies of water being sampled at the same time than ever before. We hope you find this planetary connection exciting, challenging and important.

In measuring the quality of water on your study site, you will learn much about an important part of your local environment and how it changes throughout the year.

We are very interested in your data and are excited about using the data to answer questions about planetary and local hydrology. So please let us hear from you. As the year progresses, you will hear from us with suggestions about how to interpret your data. We hope that together we can find answers to important water-quality questions.

Very truly yours,

Drs. Roger C. Bales & Martha H. Conklin
Professor & Associate Professor
University of Arizona
Tucson, Arizona, U.S.A

Duplicate and distribute to students.

Meet Dr. Roger C. Bales and Dr. Martha H. Conklin

Roger C. Bales and Martha H. Conklin teach and conduct research in hydrology and water resources at the University of Arizona in Tucson, Arizona, U.S.A.

GLOBE: *You are co-principal investigators for GLOBE's Hydrology measurements and you're married to each other?*

Dr. Conklin: Right. We have a two-year old girl and just had a little boy in January.

GLOBE: *You are a husband-and-wife scientific team. How did you meet?*

Dr. Conklin: We met at graduate school. We were both interested in water chemistry.

GLOBE: *Water is H_20. What is your interest in its chemistry?*

Dr. Bales: It's the impurities in water that are of interest and concern.

Dr. Conklin: You won't find pure water in nature because it is a universal solvent. All kinds of materials either dissolve in it or are deposited into it. A purpose of GLOBE is to understand what occurs in water and what happens when substances like chemicals are added to it.

Dr. Bales: According to the head of the U.S. Environmental Protection Agency, about 40% of the surface waters in this country are not fishable and swimmable. Often it's the smaller bodies of water, including many in agricultural areas, that are substandard. You would think that somebody is monitoring their quality, but in most cases, that's not so. Through GLOBE, we'll get information on many more streams, rivers and lakes.

Dr. Conklin: There are many water bodies around the world and each is unique. Students taking measurements is a wonderful way to gather information.

GLOBE: *Why do you need students to collect data? Why not have scientists or graduate students collect it?*

Dr. Bales: We're only a few people. Even if we went to twice as many places, we still wouldn't have much coverage.

GLOBE: *Are you concerned about things that are put in water by natural sources? By human sources? By both?*

Dr. Bales: Both. Impurities—and by impurities I don't mean anything that's necessarily bad, just anything other than H_20—can get in the water because rocks, dust and gases dissolve. Some impurities come from the atmosphere in rainfall or snowfall, which then enter streams and lakes. Some impurities come when humans dump waste into streams or lakes.

GLOBE: *You mentioned the exposure of water to rocks. Do rocks dissolve in water?*

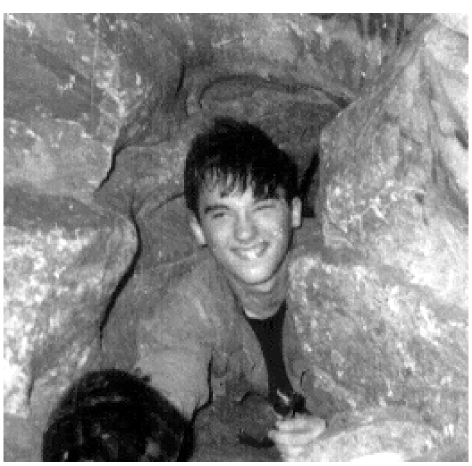
Dr. Conklin: Yes, but very slowly. You can see the long-term-effect in old mountain ranges like the Appalachians. They're weathered and not so high.

GLOBE: *Why would bodies of water near agriculture be polluted?*

Dr. Bales: Growing crops involves the use of fertilizers and pesticides. You want the fertilizer and pesticides to stay in the field for the crops or to control pests. Unfortunately, rainwater and irrigation water carry some of those away to streams and lakes. Or into the ground water.

GLOBE: *Have students collected data for hydrologists before?*

Dr. Conklin: Students have collected data on lake and river systems, but not on GLOBE's scale.



The young Roger Bales spelunking at age 16.

GLOBE: *Tell us a little about yourselves. Where you were born? Where did you grow up?*

Dr. Bales: I was born in Lafayette, Indiana, and graduated from high school in Bloomington, Indiana. I got a degree from Purdue University in civil and environmental engineering.

Martha Conklin at age 15 on the Brighton sea shore.

Then I took a master's degree in the same fields at the University of California in Berkeley.

Dr. Conklin: I was born in New Jersey, but soon my family moved to Illinois. Then we moved to Europe, which was quite a contrast. We lived in Holland for five years, where I became interested in science. Then I went to boarding school in England for two years, then came back and finished high school outside Boston.

GLOBE: *Did anyone discourage you from pursuing science because you were a woman?*

Dr. Conklin: No. I went to mainly all-girl schools, so there was never any question about whether girls could do science or math.

GLOBE: *When did you get into hydrology?*

Dr. Conklin: In graduate school. I became interested in what reactions occur in atmospheric droplets. So I studied water chemistry.

GLOBE: *What was happening?*

Dr. Conklin: We had just discovered that acid fogs occur, which are worse than acid rain. A rain droplet falls through the atmosphere quickly, picking up pollutants in the air, but fog droplets can be in the air for hours. They absorb more pollutants, and animals and people are more likely to breathe them.

GLOBE: *What do you do for fun and recreation?*

Dr. Bales: Play with our kids. We also have two Labrador retrievers and a cabin in the mountains above Tucson. I'm an avid hiker, mountain climber and skier, and we still do as much of that as we can, as well as ride our bicycles.

GLOBE: *Have you had an Archimedes-like "Eureka!" when you made a discovery on something you'd been working on?*

Dr. Conklin: I'm an experimentalist, not a theorist. I do laboratory experiments to try to understand processes that occur. I get excited when the data from lab experiments do not match what I think is going to happen. The fun thing is trying to figure out what actually is happening.

GLOBE: *As a scientist you find failed experiments beneficial?*

Dr. Conklin: Right. They are much more beneficial than if they turned out the way I thought they would. If it turns out that the results are different, that implies that my hypothesis is incorrect and I have to come up with a new one. That's the exciting thing about science.

GLOBE: *So science would be almost boring if the hypothesis was always correct?*

Dr. Conklin: Terribly boring!

GLOBE: *When you understand the mechanism of something, does that mean that you can predict what will happen?*

Dr. Bales: Exactly. Once we understand why things happen, we can say, "Well, if we have changes in the future, this is how the stream is going to respond." I'm in the business of predicting how streams or lakes respond to things like climate variability, global climate change or acid deposition.

GLOBE: *What is acid deposition?*

Dr. Bales: That's when rain or snow has a very low pH because it has dissolved strong acids from the atmosphere, many of which are produced by human activity. Acid rain plays havoc with a number of ecological niches.

GLOBE: *I think of acid as something that burns the skin. Yet acid rain* *doesn't feel different from any other kind of rain. What is it about acid rain that makes it acid rain?*

Dr. Bales: It's a strong acid that's mixed with water. It has a lower pH than natural rainfall. It's not as acidic as lemon juice or battery acid or something like that. But it could be as acidic as vinegar. In extreme cases, fog water could be as acidic as lemon juice. The main source of the acidity is the burning of fossil fuels such as gasoline, coal, and natural gas.

GLOBE: And the emissions from the burning of these fossil fuels get into the atmosphere and interact with the water?

Dr. Bales: Rainfall or snowfall scavenges these acids out of the atmosphere and they come back down to Earth. What goes up, comes down.

GLOBE: What are the rewards of science? What do you get out of it?

Dr. Bales: You feel you're contributing to an understanding of society's potential problems, and hopefully you're contributing to solutions. We examine the past, as in the case of Greenland, in order to get a clue to what the future may hold. How our environment may change as we burn more fossil fuels and change our atmosphere and waters.

Dr. Conklin: One of the most exciting things about science is that I keep getting new knowledge and in doing so, I also keep meeting new people. If I don't know something about a field, I'll find someone who does. So I also make new friends.

Dr. Bales: People need to make intelligent decisions about the Earth, even if they do so just as voters. So when I teach students about climate warming, about air pollution, about water pollution so they understand the Earth a little better, I find that very rewarding.

GLOBE: Don't you already know enough? What drives you to want to know more?

Dr. Conklin: Environmental systems have so many components to them that it's impossible for one person to ever know enough to understand them totally, but the more you know, the better your guesses are about what's happening to them.

GLOBE: Did you have heroes when you were growing up?

Dr. Conklin: One reason I'm interested in environmental science is that I always felt a need to make the world a better place. So if I have heroes it's the scientists who have tried to do that. Two are Linus Pauling, who got Nobel Prizes in both chemistry and peace, and Albert Einstein.

GLOBE: Do you have international colleagues?

Dr. Bales: Of course. We can't do everything ourselves and they can't do everything themselves, so we cooperate and share resources and data.

GLOBE: *As scientists, what are your days like? Do you have labs?*

Dr. Conklin: My average day now is working in my office, teaching, interacting with students, preparing classes, writing, analyzing my students' data, working on the computer a lot. I go into the lab to see how people are doing.

GLOBE: *It sounds like more and more scientific work is occurring on the computer. Is that true?*

Dr. Bales examining ice cores on the Greenland ice sheet

Dr. Conklin: Yes, collecting data is not enough. You have to understand it. So a lot of data analysis is done on the computer.

Dr. Bales: Most days, I spend a few hours preparing and teaching class. Then I spend an hour or two at the computer, corresponding with other scientists, reading and commenting on my students' work, or outlining things for my collaborators. Then I spend an hour or two with my graduate students. The rest gets taken up by meetings and university business.

GLOBE: *Have you any funny anecdotes about your work?*

Dr. Bales: I work a lot in mountain snowcaps because most of the water there falls as snow rather than rainfall, at least in the western U.S. And it seems ironic that I went to school all these years to get a Ph.D. only to go out and spend days digging holes in the snow with a shovel! When my mother sent me to college, she didn't tell me I'd be digging holes someday.

GLOBE: *So scientists can measure the introduction of impurities into the atmosphere by examining ice core samples that have been around for 100, 10,000 or even 100,000 years?*

Dr. Bales: Yes. In fact, I spent four weeks last summer on the Greenland ice sheet drilling ice cores. I slept in a tent on the ice for about 12 days.

GLOBE: *So you're surrounded by ice. Anything else?*

Dr. Bales: It's all white and blue. Snow and sky. Of course, the sun didn't set because we were way up north in the summer or spring. We were drilling ice cores and wanted to get done as soon as possible before a storm came in. You see the advent of the Industrial Revolution in the ice. A period of over three hundred years is very clear in the ice cores we did last summer. We also see forest fire signals in the ice core.

GLOBE: *How do you hope students will benefit from GLOBE?*

Dr. Conklin: I hope students learn how to determine the health of an environmental system. Society assumes that we can keep dumping pollutants and somehow the environment will take care of them. I hope that by checking their water systems and so on, students have some sense of whether they are healthy or polluted. I also hope they learn how to make good measurements.

GLOBE: Why should a student today consider entering your field?

Dr. Conklin: Water is one of our most important resources. Hydrology is a very good field that will become more important as clean water becomes scarcer.

Dr. Bales: Students want to do something that is not only interesting and gets them outdoors, but also contributes to a better environment and a better society. Our profession definitely does that because water is fundamental to all life on Earth.

GLOBE: Do you have any advice for students who want to get involved in Earth sciences or hydrology in particular?

Dr. Conklin: I hate to say it, but learn the basics. Math, physics, chemistry, biology. And learn how to ask questions, because those who ask the right questions will make the most important discoveries. And also learn how to write.

GLOBE: Why do you have to learn how to write?

Dr. Conklin: You could be brilliant, but if you can't communicate your results to other people, no one will know about them.

Dr. Bales: And learn as much about nature by direct experience as you can.

Introduction

Hydrology

The Big Picture

We do not just drink water; we are water. Water constitutes 50 to 90 percent of the weight of all living organisms. It is one of the most abundant and important substances on the Earth. Water sustains plant and animal life, plays a key role in the formation of weather, helps to shape the surface of the planet through erosion and other processes, and covers roughly 70% of the Earth's surface.

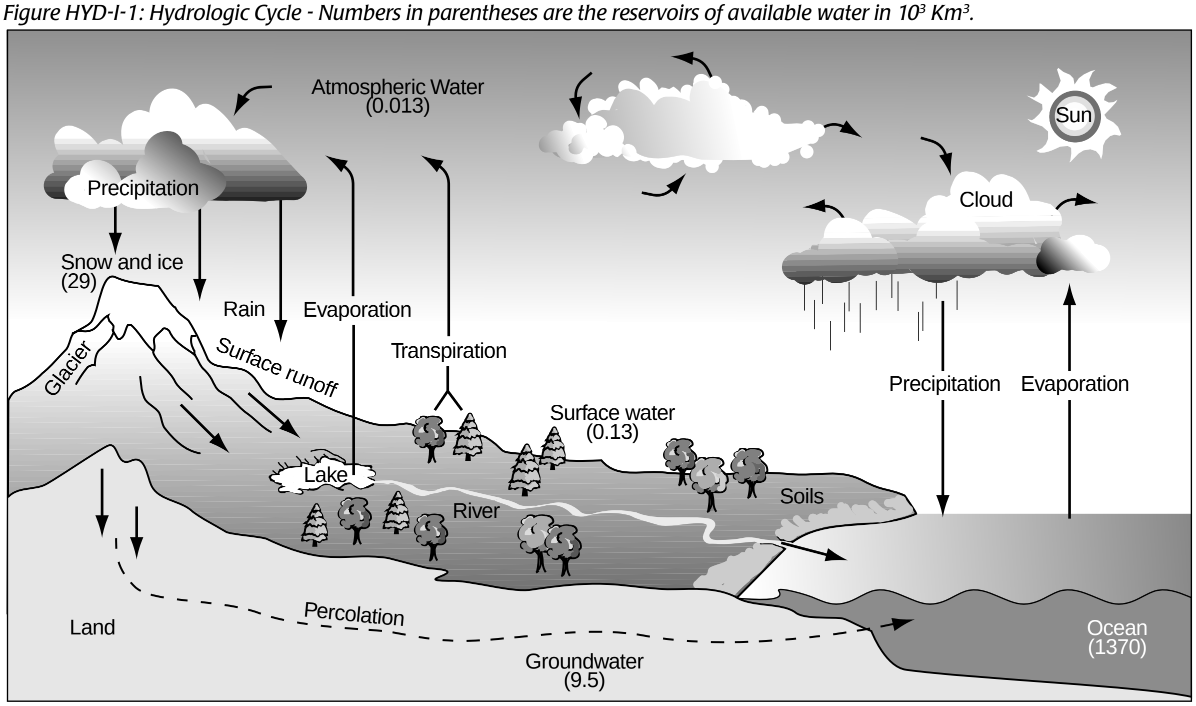
Water continually circulates between the Earth's surface and its atmosphere in what is called the hydrologic cycle. The hydrologic or water cycle, is one of the basic processes in nature. Responding to heat from the sun and other influences, water from the oceans, rivers, lakes, soils and vegetation evaporates into the air and becomes water vapor. The water vapor rises into the atmosphere, cools, and turns into liquid water or ice, forming clouds. When the water droplets or ice crystals get large enough, they fall back to the surface as rain or snow. Once on the ground, water does one of three things; some of it filters into the soil and is either absorbed by plants or percolates downward to groundwater reservoirs. Some runs off into streams and rivers and eventually into the oceans. Some evaporates.

The water in a lake, the snow on a mountain, the humid air or the drop of morning dew are all part of the same system. The total annual water loss from the surface of the planet equals the Earth's total annual precipitation. Changing any part of the system, such as the amount of vegetation in a region or land uses, affects the rest of the system.

Despite its abundance, we cannot use most of Earth's water. If we represent the Earth's water as 100 liters, 97 of them would be seawater. Most of the remaining three would be ice. Only about 3 mL out of the whole 100 liters would be water that we can consume; that water is pumped from the ground or taken from fresh water rivers and lakes.

Water participates in many important chemical reactions, and most substances are soluble in water. Due to its effectiveness as a solvent, truly

Figure HYD-I-1: Hydrologic Cycle - Numbers in parentheses are the reservoirs of available water in 10^3 Km^3.



After Mackenzie and Mackenzie 1995, and Graedel and Crutzen, 1993 pure water rarely occurs in nature. Water carries many natural and human-introduced impurities as it travels through the hydrologic cycle. These impurities give each water its distinctive chemical makeup, or *quality*. Rain and snow capture small dust particles or *aerosols* from the air, and sunlight causes emissions from the burning of gasoline and other fossil fuels to react with water to form sulfuric and nitric acids. These pollutants return to Earth as *acid rain or snow*. The acids in the water slowly dissolve rocks, placing *dissolved* solids in water. Small but visible pieces of the rocks and soils also enter the water, resulting in *suspended* solids and making some waters turbid. When water percolates into the ground, it is in very close contact with rocks and more minerals dissolve into the water. These impurities dissolved or suspended in water determine its quality.

In this investigation, students will measure the following key indicators of water quality.

Transparency

Light, essential for growth of green plants, travels further in clear water than in either *turbid* water that contains suspended solids or colored water. Two methods that are commonly used to measure the transparency, or degree to which light penetrates into water, are the Secchi disk and turbidity tube. Secchi disk transparency was first measured in 1865 by Father Pietro Angelo Secchi, scientific advisor to the Pope. This simple and widely used measurement is the depth at which a 20-cm black and white disk lowered into water just disappears from view, and reappears again when raised. An alternate measure of transparency is obtained by pouring water into a tube with a pattern similar to that of a Secchi disk on the bottom and noting the depth of water in the tube when the pattern just disappears from view. The Secchi disk is used in deeper, still waters; the turbidity tube can be used with either still or flowing waters and can be used to measure shallow water sites or the surface layer of deep water sites.

Sunlight provides the energy for photosynthesis, the process by which plants grow by taking up carbon, nitrogen, phosphorus and other nutrients, and give off oxygen. Thus penetration of sunlight into a water body determines the depth to which algae and other plants can grow, and the relative amount of growth. Transparency decreases as color, suspended sediments, or algal abundance increases. Water is colored by the presence and action of some bacteria, phytoplankton, and other organisms, by chemicals leached from soil, and by decaying plant matter. Therefore, the amount of plant nutrients coming into a body of water from sources such as sewage treatment plants, septic tanks, fertilizer run-off, and wind and water born plant debris affects transparency. Suspended sediments often come from sources such as agriculture, construction, storm runoff and resuspension of bottom sediments.

Most natural waters have transparency ranging from 1 meter to a few meters. A low value, under 1 meter, would be expected in a highly productive body of water. A low value can be due as well to a high concentration of suspended solids. Extremely clear, unproductive lakes or coastal waters can have transparency up to 30 - 40 m as can the areas around coral reefs.

Water Temperature

Water temperature is largely determined by the amount of solar energy absorbed by the water and the surrounding soil and air. More solar heating leads to higher water temperatures. Water that has been used in manufacturing and discharged into a water body may also increase water temperature. Water evaporating from the surface can lower the temperature of the water but only for a very thin layer at the surface. We need to measure water temperature to understand the patterns of change over the year because the temperature of a water body strongly influences the amount and diversity of its aquatic life. Lakes that are relatively cold and have little plant life in winter bloom in the spring and summer when water temperatures rise and the nutrient-rich bottom waters mix with the upper waters. One also finds periods of mixing in the fall. Because of this mixing and the warmer water temperatures, the spring overturn is followed by a period of rapid growth of microscopic aquatic plants and animals. Many fish and other aquatic animals also spawn at this time of year when the temperatures rise and food is abundant. Shallow lakes are an exception to this cycle, as they mix throughout the year. One concern is that warm water can be fatal for sensitive species, such as trout or salmon, which require cold, oxygen-rich conditions.

Dissolved Oxygen

Water is a molecule made of two hydrogen atoms and one oxygen atom - hence, H_2O. However, mixed in with the water molecules of any body of water are molecules of oxygen gas (O_2) that have dissolved in the water. Dissolved oxygen is a natural impurity in water. Aquatic animals, such as fish and the zooplankton they feed on, do not breathe the oxygen in water molecules; they breathe the oxygen molecules dissolved throughout the water. Without sufficient levels of dissolved oxygen in the water, aquatic life suffocates. Dissolved oxygen levels below 3 mg/L are stressful to most aquatic organisms.

In the atmosphere, roughly one out of every five molecules is oxygen; in water, about one to ten molecules in every million molecules are oxygen. Vigorous mixing of air and water, such as in turbulent streams, increases the amount of oxygen dissolved in water. So does photosynthesis by aquatic plants. Oxygen is consumed by fish, zooplankton, and the bacteria that decompose organic materials. Organic materials such as dead plant and animal matter enter streams naturally in water draining from forests and grass or crop lands. Another source of organic matter is outfalls from sewage treatment plants. Whatever the source, we tend to find low dissolved oxygen levels, well under half the saturated value, in slow-moving streams near sources of organic matter. In addition, warm water holds less oxygen than cold water, so critical periods for fish and zooplankton tend to occur in summer. For example, at 25° C, dissolved oxygen solubility is 8.3 mg/L, whereas at 4° C the solubility is 13.1 mg/L.

pH

pH is a measure of the acid content of water. The pH of a water influences most of its chemical processes. Pure water with no impurities (and not in contact with air) has a pH of 7. Water with impurities will have a pH of 7 when its acid and base content are exactly equal and balance each other out. At pH values below 7 we have excess acid, and at pH levels above 7 we have excess base in the water.

The pH scale is different from the concentration scale we use for other impurities. It is logarithmic, which means that a one-unit change in pH represents a factor of ten change in the acid content of the water. Thus water with a pH of 3 has ten times the acid content of water with a pH of 4, which in turn has ten times the acid content of water with a pH of 5.

Natural, unpolluted rain has a pH between 5 and 6, so even rain water from the least polluted place on Earth has some natural acidity. This natural acidity is the result of carbon dioxide from the air dissolving in the rain drops. Distilled water which is in equilibrium with the air will have this same pH. The most acidic rain has a pH of about 4, though urban fogs with pH of less than 2 have been measured. Most lakes and streams have pH's in the range of 6.5 to 8.5. One can find waters that are naturally more acidic in areas with certain types of minerals in the soil, (e.g., sulfides). Mining activity can also release acid-causing minerals to a stream. Naturally basic waters are found typically in areas where the soil contains minerals such as calcite or limestone.

The pH of a water body has a strong influence on what can live in it. Salamanders, frogs and other amphibian life are particularly sensitive to low pH. Most insects, amphibians, and fish are absent in water bodies with pH below 4.

Electrical Conductivity

Pure water is a poor conductor of electricity. It is the impurities in water, such as dissolved salts, that enable water to conduct electricity. Since we lack the time or money to analyze water for each substance, we have found a good indicator of the total level of impurities in fresh water to be its electrical conductivity - how well a water passes electrical current. The more impurities in water, the greater its electrical conductivity.

For most agricultural and municipal uses, we want water that has a total dissolved solids content well below 1000-1200 parts impurity per million parts water by weight (ppm), or an electrical conductivity (ability to pass electrical current) below about 1500-1800 microSiemens/cm (Note that 1 ppm = 1mg/L). Above these levels, one can expect damage to sensitive crops. For household use, we prefer water with a total dissolved-solids content below about 500 ppm, or below a conductivity of about 750 microSiemens/cm. The residues left on "clean" dishes just out of the automatic dishwasher are a product of dissolved solids in water. Manufacturing, especially of electronics, requires impurity-free water. Pure, alpine snow from remote areas has a conductivity of about 5-30 microSiemens/cm.

Salinity

The sea is salty; it has a much higher dissolved solids content than do fresh waters. Salinity is a measure of that saltiness and is expressed in parts impurity per thousand parts water. The average salinity of the Earth's oceans is 35 parts per thousand (35 ppt). Sodium and chloride, the components of common table salt (NaCl), contribute the most to the salinity. Since the proportion of chloride in seawater changes little from place to place we can also measure the chloride content, referred to as chlorinity, to estimate the total salinity. In bays and estuaries we can find a wide range of salinity values, since these are the regions where freshwaters and seawater mix. The salinity of these *brackish* waters is between that of freshwater, which averages 0.5 ppt, and seawater.

Every continent on Earth also has inland lakes that are saline. Some of the more prominent examples are the Caspian Sea in Central Asia, the Great Salt Lake in North America, and several lakes in the Great Rift Valley of East Africa. Some of these are even more saline than seawater. Waters acquire salinity because rivers carry salts that originated from the weathering or dissolving of continental rocks. When water evaporates the salts stay behind, resulting in a buildup of dissolved material. At some point the water becomes *saturated* with solids, they precipitate out as solids, and they settle out of the water. Whereas the ocean's salinity changes slowly, over many millennia, the salinity of inland waters can change more quickly when rainfall or snowmelt patterns change.

The salt content of a water body is one of the main factors determining what organisms will be found there. Thus fresh waters and saline waters are inhabited by quite different organisms. Plants and animals that live in or use freshwater (below 1 ppt) generally have a salt content inside their cells that is greater than the water they inhabit or use. They tend to give off salts as waste products. Saltwater plants and animals have a salt content equal to or less than the salinity of the surrounding water, and thus have different mechanisms for maintaining their salt balance. In brackish waters (salinity values of 1 - 10 ppt) we find plants and animals that can tolerate changes in salinity.

Alkalinity

Alkalinity is the measure of a water's resistance to the lowering of pH when acids are added to the water. Acid additions generally come from rain or snow, though soil sources are also important in some areas. Alkalinity is generated as water dissolves rocks containing calcium carbonate such as calcite and limestone. When a lake or stream has too little alkalinity, typically below about 100 mg/L, a large influx of acids from a big rainfall or rapid snowmelt event could (at least temporarily) consume all of the alkalinity and thus drop the pH of the water to levels harmful for amphibians, fish or zooplankton. We find lakes and streams in areas with little soil, such as in mountainous areas, are often low in alkalinity. These water bodies can be particularly sensitive in the spring during periods of rapid snowmelt. Because pollutants tend to wash out of a snowpack during the first part of snowmelt, we often encounter a higher influx of acidic pollutants in spring, which is also a critical time for the growth of aquatic life.

Nitrate

Plants in both fresh and saline waters require three major nutrients for growth: carbon, nitrogen and phosphorus. In fact, most plants tend to use these three nutrients in the same proportion, and cannot grow if one is in short supply. Carbon is relatively abundant in the air as carbon dioxide which dissolves in water, so a lack of either nitrogen or phosphorus generally limits the growth of aquatic plants. In some cases trace nutrients such as iron can also be limiting, as can sunlight. Nitrogen exists in water bodies in numerous forms: dissolved molecular nitrogen (N_2), organic compounds, ammonium (NH_4^+), nitrite (NO_2^-) and nitrate (NO_3^-). Of these, nitrate is usually the most important. Nitrite is usually only present in suboxic waters (low dissolved oxygen levels). The nitrate form of nitrogen found in natural waters comes naturally from the atmosphere in rain, snow, fog or dry deposition, or from the decay of organic material in soil and sediments. It can also come from agricultural runoff; farmers add nitrogen fertilizer to crops, some of which drains out of the soil when it rains.

When an excess amount of a limiting nutrient such as nitrogen is added to a lake or stream the water becomes *enriched* and further growth of algae and other plants ensues. We call this process of enriching the water *eutrophication*. The resulting excess plant growth can cause taste and odor problems in lakes used for drinking water, can cause nuisance problems for users of the water body, or can adversely affect fish and other aquatic animals. Concerns about excess nitrogen or phosphorus in lakes and coastal waters are often associated with sewage discharges. Concentrations of nitrate should always be expressed as elemental nitrogen. Thus nitrate is expressed as nitrate nitrogen (NO_3–N) in milligrams per liter (that is, 14 g of nitrogen per mole of NO_3^-) and never as NO_3 (that is 62 g per mole NO_3^-). Most natural waters have nitrate levels under 1 mg/L nitrate nitrogen, but concentrations up to 10 mg/L nitrate nitrogen are found in some areas.

The Importance of Measurements

What is the condition of the Earth's many surface waters - the streams, rivers, lakes, and coastal waters? How do these conditions vary over the year? Are these conditions changing from year to year? Through the GLOBE *Hydrology Investigation*, your students, together with students at other GLOBE schools, address these questions by continuous, widespread monitoring of natural waters. Our knowledge of national and global trends in water quality is based on sampling at a very few representative sites. This sampling has generally been done only a few times. For example, our information on many lakes is based on sampling done only once or twice more than ten years ago. Before we can assess changes, we need reliable information on current conditions. When changes are already underway, comparison of affected and unaffected areas can help us understand what is happening.

Measures of dissolved oxygen and pH directly indicate how hospitable a body of water is to aquatic life. Again, it is interesting to both follow the annual cycle of dissolved oxygen, alkalinity and pH, and to make comparisons between different water bodies. We can ask such questions as: are dissolved oxygen levels always at the maximum allowed by the temperature of the water, or are they depressed during part of the year? If they are low, we want to know the cause. We can see if pH becomes depressed right after a rain or when there is a lot of snowmelt running off into the lake or stream. If we do find a depression in pH, we would expect that this water had a low level of alkalinity. In fact, we should expect that waters with a low alkalinity would have a depression in pH following rainfall or snowmelt. But we must make the measurement to confirm whether or not that really happens.

Students should make this suite of GLOBE measurements with at least two societal goals in mind. First, we want to develop a better understanding of our local land and water resources. This knowledge can help us make more intelligent decisions about how we use, manage and enjoy the resources. Second, we want to assess the extent to which human activities are affecting the quality of our water and thus affecting how we will be able to use it in the future. In most countries current measurement programs cover only a few water bodies at a few times during the year. We hope the measurements you make in the GLOBE program will help fill this gap and improve our understanding of the health of Earth's natural waters.

Preparing for the Field

Overview

Students will take samples of water from a selected body of water, process the samples to determine their composition, and analyze the data to come to better understand the quality of water and its impact on their environment.

Table HYD-I-1 lists the recommended protocols for the three levels of GLOBE. Teachers should use their own judgment as to which protocols are consistent with their students' abilities. Please note that the more advanced protocols involve special safety considerations.

Table HYD-I-1: Hydrology Measurement Levels

Level	Measurements
Beginning	transparency temperature pH (paper) conductivity or salinity
Intermediate/ Advanced	transparency temperature dissolved oxygen pH (pen or meter) conductivity or salinity alkalinity nitrate

Measurement Schedule

Measurements must be made one day per week, at the same time of day and on the same day of the week. Weekly measurements are particularly important during those times of the year when hydrology sites are undergoing rapid change. Samples can be collected for all protocols at each site visit.

Site Selection (in order of preference)

1. Stream or river
2. Lake, reservoir, bay or ocean
3. Pond
4. An irrigation ditch or other water body if one of the above is not accessible or available within your GLOBE Study Site.

Student Groups

Measurements should be taken by groups of 2-3 students. Tasks within a group include collecting samples, processing samples, and recording data. It is very useful to have multiple groups testing for each parameter (for example, two groups measure dissolved oxygen). This allows more students to get involved and builds in some quality control. Groups of students conducting the same test should look at each other's results to determine if the data are similar. If there are different results for the same sample, students should check the procedures and redo the test to determine what caused the difference. Data quality control should be an important part of the science and the learning experience.

Overview of Educational Activities

When the protocols for conducting each measurement are combined with the *Learning Activities*, a comprehensive program for understanding the chemistry of water bodies is established. There may be a temptation to have students merely take measurements and enter the data on the GLOBE data pages. However, gaining knowledge about science content, processes, and critical thinking skills are our educational goals. The *Learning Activities* will assist you in providing the context for the *Protocols*.

Student Learning Goals

This investigation develops students' understanding of the importance, unique properties and content of water. Through applications of water analyses, students come to understand water chemistry and how it is important in understanding the health of aquatic environments.

Upon completing all of the activities in this investigation, students should know and understand the following concepts and skills.

Concepts

Water chemistry is an important aspect of habitat requirements

Temperature can affect other water chemistry factors

Water chemistry affects species diversity

Instruments can enhance what your senses tell you about what is in water

Data are used to pose and answer questions

Graphs and maps are valuable tools for visualizing data

Accuracy and precision are important when taking measurements

The soil stores water, and its water content is related to the growth of vegetation

Where rainfall goes depends on your site characteristics

Higher temperatures and longer periods of sunshine increase evapotranspiration

Water flows can change over time

Water balance can be modeled using temperature, precipitation, and latitude data

Skills

Making observations

Applying field sampling techniques

Calibrating scientific equipment

Following directions in methods and test kits

Recording and *reporting* data accurately

Reading a scale

Communicating orally

Communicating in writing

Asking Questions

Forming and *testing* hypotheses

Designing experiments, tools, and models

Using water quality measurement equipment

Using tools to enhance the senses

Creating and *reading* graphs

Calculating averages

Making comparisons over space and time

Analyzing data for trends and differences

Using the GLOBE database

Student Assessment

Individual assessment of students' roles in this project and peer grading can be used, and the total study incorporated in students' portfolios. GLOBE Science Notebooks can be regularly assessed to chart the students' progress in understanding key science concepts, processes, and skills. They also can be the foundation for the development and assessment of communications skills, both written and oral. Reports and presentations should be designed using the material in the GLOBE Science Notebooks.

In addition to entering the data into the GLOBE Student Data Server, at levels where it is educationally appropriate, students should analyze their data and write reports. Have students write about the parameters they tested and compile all the individual reports into a complete study of the site. Submit the study to local and state agencies that govern water and water quality.

References

T.E. Graedel and P.J. Crutzen (1993) *Atmospheric Change: An Earth System Perspective*. W.H. Freeman and Company, New York

F.T. Mackenzie and J.A. Mackenzie (1995) *Our Changing Planet: An Introduction to Earth System Science and Global Environmental Change. Prentice* Hall, New Jersey.

Protocols

How to Perform Your Hydrology Investigation

Collecting the Water Sample

Water Transparency Protocol

Students will first measure water transparency at their undisturbed sampling site.

Water Temperature Protocol

Immediately after collecting their water sample or *in situ*, students will measure the temperature of the water.

Dissolved Oxygen Protocol

Students will measure the dissolved oxygen in their water sample or *in situ*.

pH Protocol

Students will measure the pH of their water sample. Method one uses pH indicator paper, and method two uses pH pens or pH meters.

Electrical Conductivity Protocol

Students will measure the electrical conductivity of their fresh water sample.

Salinity Protocol

Students will measure the salinity of their salty or brackish water sample using a hydrometer.

Optional Salinity Titration Protocol

Intermediate or advanced students will measure the salinity of their salty or brackish water sample using a chlorinity titration.

Alkalinity Protocol

Students will measure the alkalinity of their water sample.

Nitrate Protocol

Students will measure the nitrate-nitrogen content of their water sample.

How to Perform Your Hydrology Investigation

Preparing For Your Hydrology Measurements

Selecting the Hydrology Study Site

Ideally, the Hydrology Study Site will be within a watershed that is a prominent feature in the 15 km x 15 km GLOBE Study Site. Within this watershed, select a specific site where the hydrology measurements (water temperature, transparency, pH, dissolved oxygen, alkalinity, electrical conductivity or salinity, and nitrate) will be taken. If there is a water body of special interest within your watershed, by all means choose that. Otherwise, the water bodies in order of preference are:

1. Stream or river
2. Lake, reservoir, bay, or the ocean
3. Pond

An irrigation ditch or other water body may be used if one of the above is not accessible or available within your GLOBE study site.

You should collect all water samples from the same place at the hydrology site each time. This is called the sampling site.

If the site is a moving body of water, like a stream or a river (*lotic*), locate your sampling site at a riffle area (a place where the water is moving but not too fast) as opposed to still water or rapids. If the site is a still body of water, like a lake or reservoir (*lentic*), find a sampling site near the outlet area or along the middle of the water body, but avoid taking samples near an inlet. A bridge or a pier are good choices. If your brackish or salty water body is affected by tides, you will need to know the times of high and low tide at a location as close as possible to your study site.

Site Description

Once you have selected your hydrology site, be sure to identify the coordinates of this site with the GPS receiver. Enter the location plus other site description information requested on the Hydrology Investigation Site Selection Data Entry Sheet. For the salinity protocols, you will need to know the latitude and longitude of the location for which you will report the times of high and low tide. You can measure these using a GPS receiver and following the *GPS Protocol* or obtain them from those who provide the high and low tide information.

Frequency

Collect all water-chemistry measurements at roughly the same time each day, on a weekly basis. If your sampling site freezes over in winter or runs dry, be sure to enter this information on the data sheet each week until you again have free-flowing surface water to measure.

Note: Certain times of the year provide more exciting measurements. When runoff is occurring on a river, the increased flow and sediment will dramatically change water-chemistry measurements. Just after ice melts off a lake is also a dramatic time because various layers of water in the lake are mixing with layers near or at the bottom of the lake. Often layers near the bottom end up on top near the surface, thus adding surprising changes to your measurement results. Be observant of seasonal and monthly changes.

Quality Assurance and Quality Control

A quality assurance and quality control (QA/QC) plan is necessary to ensure that test results are as accurate and precise as possible. Accuracy refers to how close a measurement is to true value. Precision means the ability to obtain consistent results. Reliability in both accuracy and precision is achieved by:

- Collecting the water sample as directed
- Performing tests immediately after collecting the water sample
- Careful calibration, use and maintenance of testing equipment

- Following the specific directions of a protocol exactly as described
- Repeating measurements to check their accuracy and to understand any sources of error
- Minimizing contamination of stock chemicals and testing equipment
- Checking to be sure the numbers submitted to the GLOBE Student Data Server are the same as those recorded on the Hydrology Investigation Data Work Sheet.

Calibration

Calibration is a procedure to check the accuracy of testing equipment. For example, to ensure that the pH instruments are functioning properly, a solution of known value is tested. Calibration procedures vary among the measurements and are detailed in each protocol. Certain calibrations must be done the same day as the field measurements. Some calibration procedures may be done in the classroom just before taking the equipment out into the field. However, in some cases, it may be necessary to check the calibration again in the field by doing a field measurement of a known value solution. See *pH* and *Electrical Conductivity Protocols*.

Promptness and Sequence When Making Measurements

Testing for transparency, temperature, and dissolved oxygen should be done on site (*in situ*) immediately after obtaining the water sample. Do not let the bucket of water sit for more than a half hour before taking measurements. Take a new sample if this happens. If unavoidable, samples may be bottled (see Bottling Technique in collecting your water sample) and tested in the classroom. However, we strongly recommend that all testing be done at the sampling site. We do not recommend doing the dissolved oxygen test in the classroom since the analysis should be done within 30 minutes of collection. Measurement of pH and nitrate (within 2 hours), alkalinity, electrical conductivity or salinity (within 24 hours) may be done later in the classroom if necessary.

Important: The sequence in which the measurements are performed is important. Transparency measurements should be taken first, followed immediately by the water temperature measurements and the dissolved oxygen test, then pH, electrical conductivity or salinity, alkalinity, and nitrate.

Important: Dissolved oxygen measurements have limited value unless the temperature of the water is known. Measure dissolved oxygen only if you measure water temperature. If your site is a salty or brackish water you also must measure salinity in order to interpret the dissolved oxygen measurements.

Repeated Measurements

Divide your class into at least two groups for each measurement. Once one group has finished their measurement, have them hand the equipment to the second group. Both groups use the same bucket of water for the measurement.

If the values found by the two groups differ significantly, the measurement should be repeated by a third group and perhaps repeated by the first two groups. The following are the maximum acceptable differences between measured values.

Measurement	Maximum Difference
Transparency	1.0 cm
Water Temperature	0.5° C
Dissolved Oxygen	0.4 mg/L (La Motte kit) 1.0 mg/L (Hach kit)
pH (using paper)	1.0 pH unit
pH (using pen or meter)	0.2 pH unit
Conductivity	2% of full scale (40 µS/cm)
Salinity (hydrometer)	0.4 parts per thousand
Salinity (titration kit)	0.4 parts per thousand
Alkalinity	4 mg/L as $CaCO_3$ (La Motte Kit) 1 drop (Hach Kit): 17 mg/L as $CaCO_3$ (high range) 6.8 mg/L as $CaCO_3$ (low range)
Nitrate	1.0 mg/L

Each group should use its own Hydrology Investigation Data Work Sheet. The value submitted to the GLOBE Student Data Server should be an average of all values obtained that meet the above criteria. Discard values that fall far outside the maximum differences. Note that for water transparency, all values should be submitted to the GLOBE Student Data Server.

Disposal of Liquid Waste

After tests have been conducted, all solutions (except for the nitrate analysis and salinity titration) and liquids should be collected in a wide-mouthed screw top plastic waste container and disposed of in a school sink or utility sink, and flushed with excess water. Or, they should be disposed of according to your local school district's safety procedure guidelines. The wastes from the nitrate analysis and the salinity titration (which typically contain cadmium and chromate, respectively) should be disposed of according to your local school district's safety procedure guidelines.

Collecting the Water Sample

Materials and Tools

4-L bucket with a strong rope attached securely to the handle
Paper towels
500 mL-polyethylene sample bottles
GLOBE Science Notebooks, pens, Data Work Sheets
Latex gloves (recommended)

If students can SAFELY reach the water body (within arms' reach), water temperature, pH, dissolved oxygen, and electrical conductivity measurements can be taken *in situ* directly at the water's edge. However, the measurements of alkalinity, salinity, and nitrate require a sample to be taken with a bucket. The water samples should be tested immediately after they are obtained. If unavoidable, samples may be bottled and tested for pH, alkalinity and salinity or electrical conductivity after returning to the classroom. The oxygen in the water must be stabilized by doing the initial steps of the dissolved oxygen protocol before the sample can be transported. Use the following techniques to obtain water samples for immediate testing and to bottle samples for testing in the classroom.

A sample of surface water can be used with the turbidity tube. The Secchi disk measurement is only appropriate for deeper water and measurements are generally taken from a bridge or pier, away from the water's edge.

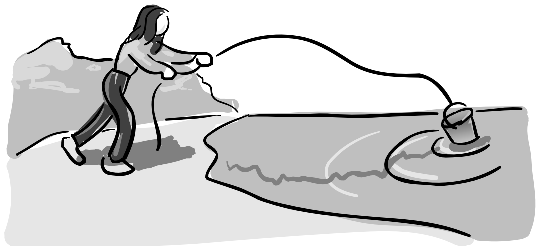
Sampling Technique

1. Holding onto the rope, lower the bucket into the water and allow it to fill partially with water. If the bucket sits on its end, its lip is not lowering enough to allow water into it; jostle it with the rope. Once some water enters the bucket, retrieve the bucket and swirl the water around to clean out the bucket. Discard this water and repeat the procedure once more. Do not use distilled water to rinse the bucket as this will change the sampling results. Likewise never let the sampling bucket be used for cleaning or other purposes since this will also affect the sampling results.

   If your sampling site is a stream, throw the bucket out to a well-mixed area, a little distance from the shore. Ideally, the water should be flowing at least slightly. If you are sampling from a fast-moving stream, grip the bucket rope tightly so the force of the water's flow does not take your bucket with it.

   If you are sampling from a lake, bay, or the ocean, take samples from the shore and throw the bucket out as far as possible to take your sample. You should always take a sample from the top surface water. Do not let the bucket fill up and

Rinsing the water bucket.



Casting the bucket.

sink. Also be careful not to stir up bottom sediment.

2. To obtain a sample, allow the bucket to fill to about 2/3 to 3/4 full. Then hoist the bucket out of the water.

Bottling Technique

While the preferred procedure is to do all testing at the Hydrology Study Site, measurements of pH, alkalinity, nitrate and electrical conductivity or salinity can be done in the classroom. The dissolved oxygen protocol can be completed in the classroom after the dissolved oxygen has been stabilized in the field.

Use the following procedure to bottle sample water and transport it to the classroom for all but temperature, dissolved oxygen and transparency measurements.

1. Label a 500-mL polyethylene bottle with your school's name, the teacher's name, the site name, the date and time of collection.
2. Rinse the bottle and cap with sample water.
3. Fill the bottle with sample water until the water forms a dome shape at the top of the bottle so that, when the cap is put on, no air is trapped inside.
4. Seal the cap of the bottle with masking tape.

   Note: Tape serves as a label, and an indicator of whether the bottle has been opened. Tape should NOT be in contact with the water sample itself.
5. Store these samples in a refrigerator at about 4° C until they can be tested (within 2 hours for pH and nitrate and within 24 hours for alkalinity and salinity or electrical conductivity).
6. Once the seal is broken, do the pH test first, then the tests for salinity or electrical conductivity, alkalinity, and nitrate. Ideally, once opened, all the measurements should be performed during the same lab session.

Safety

• Consult the Material Science Data Sheets (MSDS) that come with kits and buffers. Also consult your local school district's safety procedure guidelines.

• In any cases where using kits with chemicals, latex gloves and safety goggles are recommended.

Water Transparency Protocol

Purpose

To determine water transparency using a Secchi disk (still, deep waters) or turbidity tube (flowing or shallow waters)

Overview

The Secchi disk is a widely used measure of the transparency of water to light. The Secchi disk transparency depends on the amounts of suspended and colored material in the water, material that comes from either sediment washed into a water body or biological activity in the water body. A turbidity tube is used to measure transparency of flowing waters, or where use of a Secchi disk is impractical.

Time

10-15 minutes

Level

All

Frequency

Weekly

Key Concepts

Determining water transparency using a Secchi disk or turbidity tube
Light scattering
Suspended particles
Light absorption
Water color
Productivity

Skills

Using a Secchi disk or turbidity tube
Designing measurement strategies
Recording data
Interpreting results

Materials and Tools

Secchi disk:

5 m length of rope (or longer or shorter, depending on depth of the water at the site)
Latex enamel spray paint: black and white
2.5-3 cm diameter by 15 cm long steel pipe
Drill
Circular piece of wood 2.5 cm thick and 20 cm diameter
2 hook screws
15 cm length of string
Small bottle of wood glue or super glue
Waterproof markers (red, blue, and black)
Meter stick

Turbidity tube:

Clear plastic tube, approx. 1 m long (depending on transparency of water at your site) and 4.5 cm diameter (e.g. Clear plastic fluorescent light casing, found at hardware or lumber stores)
White cap that fits securely on the bottom of the tube (a cap to a PVC pipe fits nicely)
Black permanent marker
Meter stick

Preparation

If a Secchi disk is not ordered, one must be made. To make one, follow the directions in Design and Learning Approach.

If a turbidity tube will be used, it must be made before going to the study site.

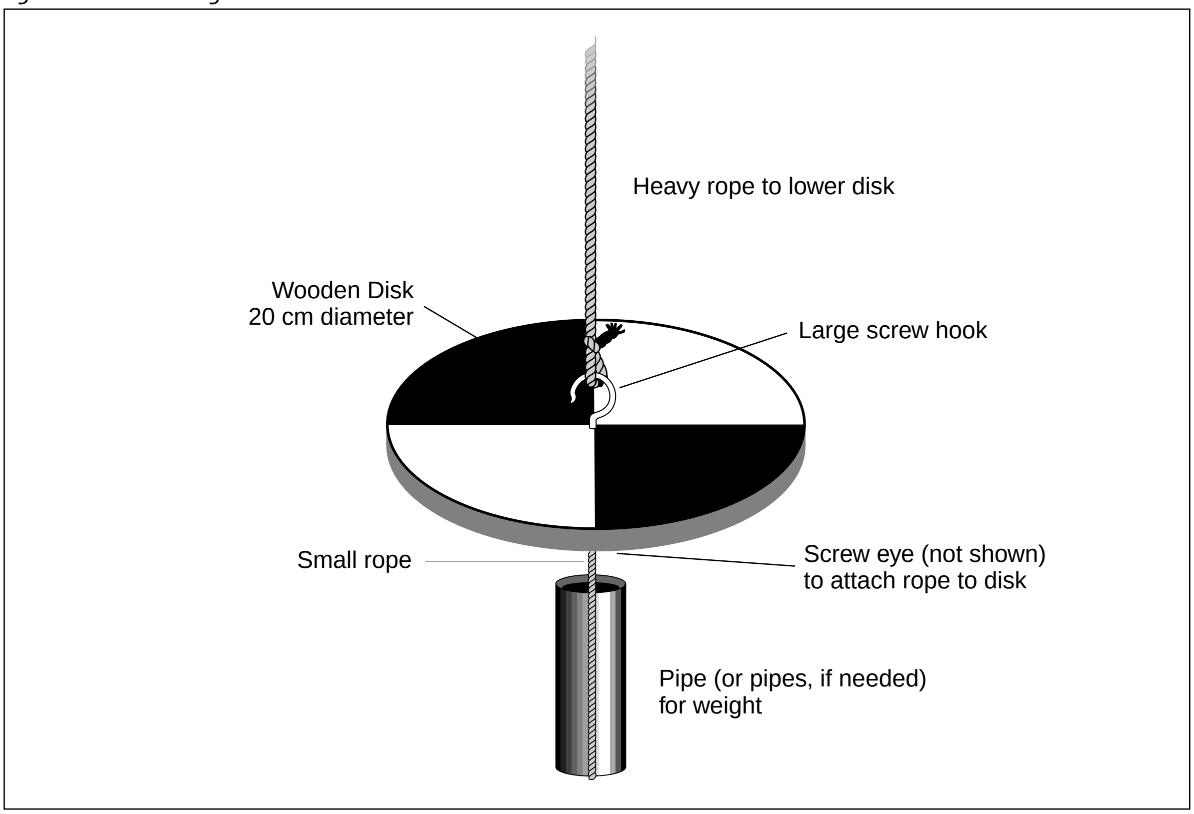
Prerequisites

A brief discussion of how the Secchi disk or turbidity tube can be used in the indication of water transparency is necessary before students make their first measurement.

To make a Secchi disk:

1. Divide top of wooden disk into four quadrants drawing lightly in pencil (draw 2 lines crossing at a 90 degree angle).
2. Paint two opposite quadrants in black and the other two in white.
3. Screw a hook screw into the top center and bottom center of the disk. Then tie the 5-m (or longer) rope through the hook screw in the top of the disk.
4. Tie a short piece of rope through the hook screw on the bottom of the disk and string it though the pipe. Tie a large knot at the bottom of the pipe so that it does not fall off when hanging vertically underneath the disk.
5. Hold the rope attached to the top of the disk and use the meter stick and measure distance from the disk. Mark rope with a black waterproof marker every 10 cm. Mark every 50 cm up from the disk with a blue marker and every meter with a red marker. Now you are ready to make a measurement.

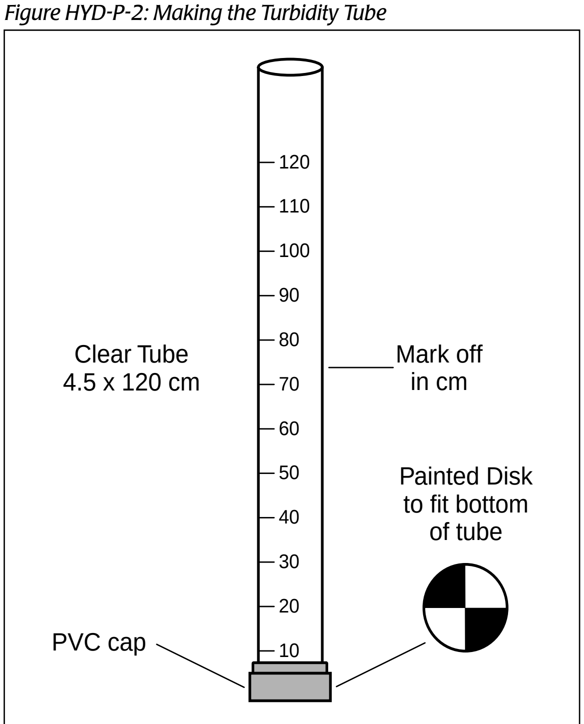
Figure HYD-P-1: Making a Secchi Disk



To make a turbidity tube:

1. Put PVC cap over one end of clear tube. Cap should fit tightly so water cannot leak out.
2. Cut a disk from wood, plastic, or cardboard the same size as the tube diameter.
3. Divide the disk into fourths. Paint alternating quadrants black and white. Seal the disk by laminating or painting with varnish to make it waterproof.
4. Glue the disk in the bottom of the tube, painted side facing up (toward the open end of the tube).
5. Use a marker and meter stick to make a scale on the side of the tube, beginning at the top of the disk with 0 cm.

Figure HYD-P-2: Making the Turbidity Tube



How to Measure Transparency

Make sure that Secchi disk and turbidity tube measurements are made in the shade with the sun to your back to make an accurate and reproducible reading. If there is no shade available, use an umbrella or a large piece of cardboard to shade the particular area where the measurement is being made. For the turbidity tube the shadow of the observer should be adequate.

Different individuals may see the Secchi disk or the bottom of the turbidity tube disappear at different water depths. For this reason, whenever possible the transparency observation should be made by three different students and each of their observations submitted to the GLOBE Student Data Server.

Secchi disk

1. Lower the disk slowly into the water until it just disappears. If possible, grab the rope at the surface of the water and mark this point on the rope (e.g. use a clothes pin). If it is not possible to mark the rope at the water surface, mark the rope a known distance above the water.
2. Then raise the Secchi disk until it just reappears into view. Grab the line at the surface of the water when the Secchi disk reappears and mark this point (or some known distance above the water). The rope should now be marked at two points. There should only be a few centimeters difference between these two points.
3. Record both depths on your Hydrology Investigation Data Work Sheet to the nearest 1 cm.
4. If the two depths differ by more than 10 cm, repeat the measurement, recording the new depths on your Hydrology Investigation Data Work Sheet.
5. Using the *Cloud Cover Protocol*, determine the cloud cover. Determine the distances between where each observer marked the rope and the water surface. Record both on your Hydrology Investigation Data Work Sheet. If the rope was marked at the water surface enter 0.

6. Submit your depths along with the cloud cover and distance from the mark to the water surface to the GLOBE Student Data Server. **Note**: Enter data for each observer, not the average of the different observations.

Note: If the Secchi Disk reaches the bottom of your study site and you can still see it, simply record the depth to the bottom by referring to the point where the rope is at the water surface and put a greater than (>) symbol in front of the measurement both on your data work sheet and when you submit the value to the GLOBE Student Data Server.

Turbidity tube

1. Pour sample water into the tube until the image at the bottom of the tube is no longer visible when looking directly through the water column at the image. Rotate the tube while looking down at the image to see if the black and white areas of the decal are distinguishable.
2. Record this depth of water on your Hydrology Investigation Data Work Sheet to the nearest 1 cm.
3. Submit your depth to the GLOBE Student Data Server. Enter data for each observer, not the average of the different observations.

Note: If you can still see the image on the bottom of the tube after filling it, simply record the depth as > the depth of the tube.

Water Temperature Protocol

Purpose
To measure the temperature of the water sample

Overview
The temperature of the water sample is needed for the dissolved oxygen and pH measurements, and for studies of global hydrology questions.

Time
5 minutes after the thermometer has been calibrated

Level
All

Frequency
Weekly

Calibration every three months

Key Concepts
Temperature, temperature measurement
Heat, heat transfer, conduction
Accuracy
Precision

Skills
Using a thermometer properly
Reading a scale
Recording data

Materials and Tools
Alcohol-filled thermometer
A clock or watch
Enough string to lower the thermometer into the water
Rubber band
Data sheets

Preparation
Bring the tools and materials to the Hydrology Study Site.

Prerequisites
None

Calibration and Quality Control

This measurement takes only a few minutes to complete. The main concern is to allow sufficient time for the thermometer to equilibrate to the temperature of the water perhaps three to five minutes.

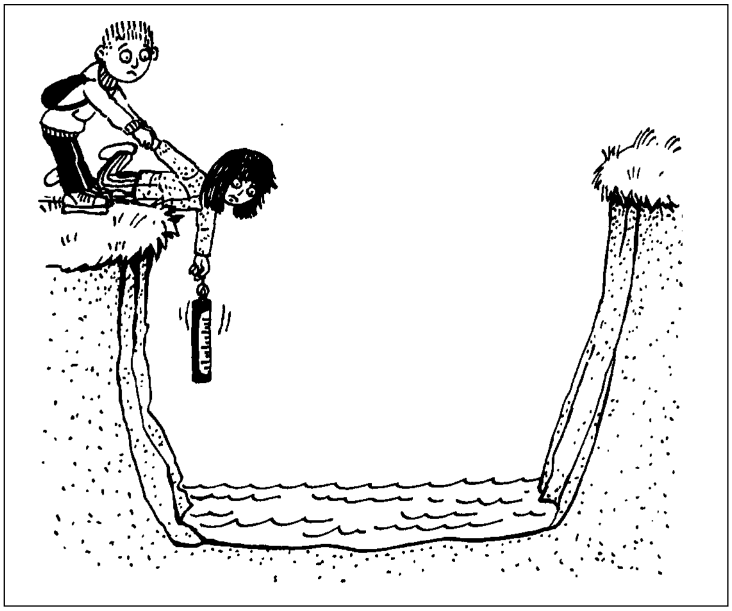
Your organic liquid-filled thermometer should be calibrated at least every three months as well as before its first use. Calibrate it following the instructions in the *Atmosphere Investigation Maximum, Minimum, and Current Temperatures Protocol.*

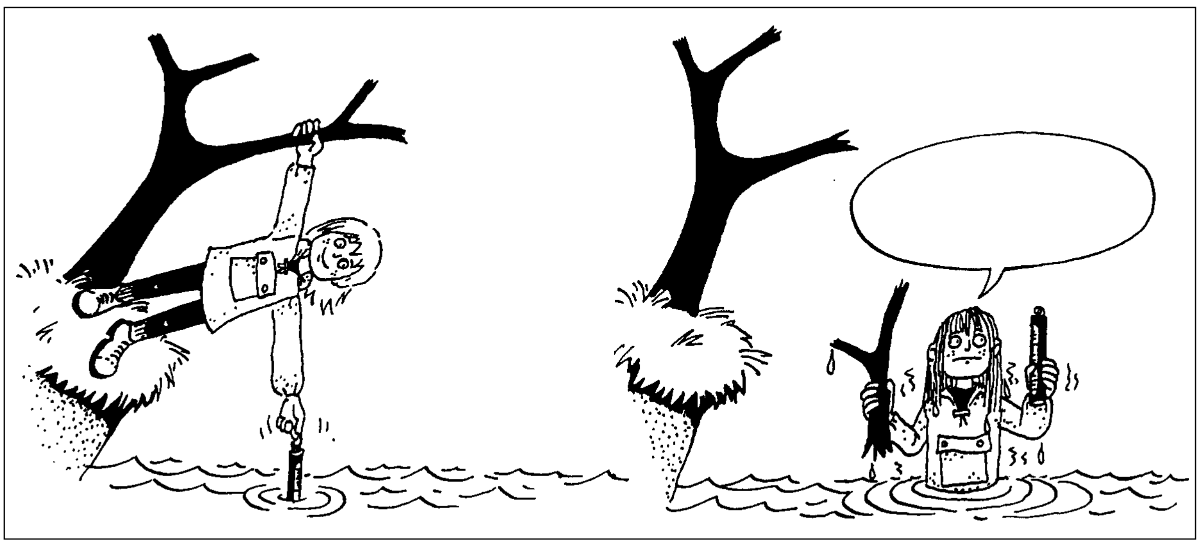
How to Measure Water Temperature

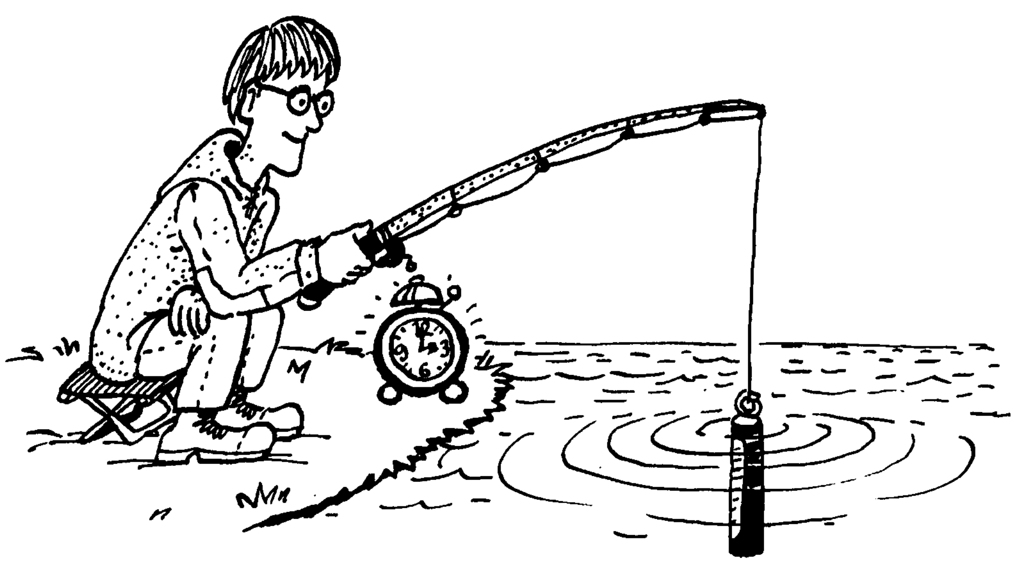
1. Tie one end of a piece of string securely to the end of the thermometer and the other end to a rubber band. Slip the rubber band around the wrist so that the thermometer is not lost if it is accidentally dropped in the water.
2. Hold the end of the thermometer (opposite the bulb) and shake it several times to remove any air in the enclosed liquid. Note the temperature reading.
3. Immerse the thermometer to a depth of 10 cm in the sample water for three to five minutes.
4. Raise the thermometer only as much as is necessary to read the temperature. Quickly note the temperature reading. If

the air temperature is significantly different from the water temperature or it is a windy day, the thermometer reading may change rapidly after it is removed from the water; try to take the reading while the bulb of the thermometer is still in the water. Lower the thermometer for another minute or until it stabilizes. Read it again. If the temperature is unchanged, proceed to Step 5.

5. Record this temperature along with the date and time on the Hydrology Investigation Data Work Sheet.
6. Take the average of the temperatures measured by the student groups. If all measured values are within 1.0° C of the average, submit the average value to the GLOBE Student Data Server. Otherwise, repeat the measurement.







Source: Jan Smolík, 1996, TEREZA, Association for Environmental Education, Czech Republic

Dissolved Oxygen (DO) Protocol

Purpose
To measure the amount of oxygen dissolved in the water sample

Overview
Dissolved oxygen is closely related to survival of plant and animal life in all bodies of water. It is affected by natural processes and by human activities.

Time
15 minutes for calibration
15 minutes in the field

Level
Intermediate and Advanced

Frequency
Weekly

Calibration every six months

Key Concepts
Dissolved oxygen
Comparing with a standard
Accuracy, Precision

Skills
Using the dissolved oxygen test kit properly
Recording data

Materials and Tools
Dissolved Oxygen Kit (See *Toolkit*)
Safety note: This kit contains hazardous chemicals
Distilled water
250-mL polyethylene bottle with top
Thermometer
Data Work Sheets
Latex gloves/safety goggles

Preparation
Practice sample preparation and preservation procedure given in this protocol.

Bring the tools and materials to the Hydrology Study Site.

Prerequisites
None

Calibration and Quality Control
Calibration should be performed every six months to verify your technique and the integrity of your chemicals.

1. Rinse a 250 mL bottle twice with distilled water. Measure 100 mL of distilled water with a graduated cylinder.
2. Pour this water into the 250 mL bottle. Put the lid on tightly and shake it vigorously for 5 minutes.
3. Uncap the bottle and take the temperature of the water. Be sure the tip of the thermometer does not touch the bottom or sides of the bottle. Wait 1 minute before reading the temperature.
4. Record the temperature on the Hydrology Investigation Data Work Sheet.
5. Follow directions to measure dissolved oxygen.

On the data sheet, record the value as mg/L DO for the distilled-water standard. The mg/L DO found using the shaken standard must be within 0.4 mg/L of the expected value for a shaken (thus saturated with oxygen) distilled water sample. To find the expected value for a saturated DO distilled water sample:

1. Look up the temperature of your standard in Table HYD-P-1.
2. Look at the corresponding solubility of oxygen (mg/L) and record it on the Calibration Data Work Sheet.

Table HYD-P-1: Solubility of Oxygen in Water Exposed to Air at 750 mm Hg Pressure

Temp ° C	Solubility mg/L	Temp ° C	Solubility mg/L	Temp ° C	Solubility mg/L
0	14.6	16	9.9	32	7.3
1	14.2	17	9.7	33	7.2
2	13.8	18	9.5	34	7.1
3	13.5	19	9.3	35	7.0
4	13.1	20	9.1	36	6.8
5	12.8	21	8.9	37	6.7
6	12.5	22	8.7	38	6.6
7	12.1	23	8.6	39	6.5
8	11.9	24	8.4	40	6.4
9	11.6	25	8.3	41	6.3
10	11.3	26	8.1	42	6.2
11	11.0	27	8.0	43	6.1
12	10.8	28	7.8	44	6.0
13	10.5	29	7.7	45	5.9
14	10.3	30	7.6	46	5.8
15	10.1	31	7.4	47	5.7

Example: a standard temperature of 22° C has a corresponding DO solubility of 8.7 mg/L.

3. Look at the Calibration Value in Table HYD-P-2 corresponding to your elevation in meters and record it on the Calibration Data Work Sheet.

   Example: An elevation of 1,544 meters has a corresponding saturation calibration value of 0.83.

4. Multiply the solubility of oxygen found in Step 2 by the calibration found in Step 3.

   Example: At an altitude of 1,544 meters and a temperature of 22° C, you multiply (8.74 mg/L) x (0.83) = 7.25.

5. This value (7.25 in the example) is your expected value for a shaken distilled water standard.
6. Compare this value to the value for DO that you found when you tested your shaken, distilled water standard. If the value is not within 0.4 mg/L (LaMotte kit) or 1 mg/L (Hach kit), try the measurement again on the distilled water. If it is still off, but by less than 1 mg/L, record the DO value on the Calibration Investigation Data Work Sheet.
7. If you get a difference of more than 1 mg/L, report the value you get and replace the chemicals in your test kit before making more measurements. Recalibrate when you get fresh chemicals.

How to Measure Dissolved Oxygen

Sampling Procedure

1. Rinse the sampling bottle and hands with sample water three times. Rinse vial three times in distilled water.
2. Replace the cap on the bottle.
3. Submerge the bottle in sample water and remove the cap. Allow the container to fill.
4. Tap the bottle to release air bubbles.
5. While the bottle is submerged, replace the cap. Remove the capped bottle from the water.
6. Check to ensure that no bubbles are present in the bottle. If bubbles are found, repeat the sampling procedure.

Sample Preservation and Testing Procedure

1. Use a dissolved oxygen test kit that meets the specifications in the Toolkit of the GLOBE Program Teacher's Guide. Follow the instructions carefully. If a scoop is used to measure powdered chemicals, do not allow the scoop to come in contact with the liquid.
2. Record the values from the student groups on the Hydrology Investigation Data Work Sheet.
3. Take the average of the DO values measured by the student groups. If the values are all within 1 mg/L of the average, submit the average DO value to the GLOBE Student Data Server. Otherwise repeat the measurement.
4. Put all liquids in waste bottle.

DO test kits involve two overall parts - sample preservation (stabilization) and sample testing. The preservation part involves the addition to the sample of a chemical that precipitates in the presence of dissolved oxygen, followed by addition of a chemical that produces a colored solution. The testing part involves dropwise addition of a *titrant* solution until the color disappears. The DO value is calculated from the volume of titrant added.

Table HYD-P-2: Calibration Values For Various Atmospheric Pressures and Altitudes

Pressure mm Hg	Pressure kPa	elev m	Calibration value %
768	102.3	-84	1.01
760	101.3	0	1.00
752	100.3	85	0.99
745	99.3	170	0.98
787	98.8	256	0.97
730	97.3	343	0.96
722	96.3	431	0.95
714	95.2	519	0.94
707	94.2	608	0.93
699	93.2	698	0.92
692	92.2	789	0.91
684	91.2	880	0.90
676	90.2	972	0.89
669	89.2	1066	0.88
661	88.2	1160	0.87
654	87.1	1254	0.86
646	86.1	1350	0.85
638	85.1	1447	0.84

Pressure mm Hg	Pressure kPa	elev m	Calibration value %
631	84.1	1544	0.83
623	83.1	1643	0.82
616	82.1	1743	0.81
608	81.1	1843	0.80
600	80.0	1945	0.79
593	79.0	2047	0.78
585	78.0	2151	0.77
578	77.0	2256	0.76
570	76.0	2362	0.75
562	75.0	2469	0.74
555	74.0	2577	0.73
547	73.0	2687	0.72
540	71.9	2797	0.71
532	70.9	2909	0.70
524	69.9	3203	0.69
517	68.9	3137	0.68
509	67.9	3253	0.67
502	66.9	3371	0.66

pH Protocol

Purpose

To measure pH

Overview

The pH or acidity of the water sample is a key factor in determining what can live in the water.

Level

All

Time

5 minutes for the actual measurements
10 to 15 minutes in class and 5 minutes in the field for calibration in Method 2

Frequency

Weekly including calibration

Key Concepts

pH and its measurement
Temperature affects pH
Calibration
pH buffers and standards

Skills

Using pH measuring equipment
Recording data

Materials and Tools

For Method 1:

pH indicator paper (Beginning)
50- or 100-mL beakers

For Method 2:

pH pen (Intermediate/Advanced)
One jewelry screwdriver (for calibration)
Three 50- or 100-mL beakers
50 mL polyethylene bottle with top or clean baby food jar with lid
pH buffer solution for pH 7

or:

pH meter (Intermediate/Advanced)
Five 50- or 100-mL beakers
Three 50-mL polyethylene bottles with tops or clean baby food jars with lid
Three pH buffer solutions for pH 4, 7, and 10

And for both pen and meter techniques:

100 mL graduated cylinder
Paper towels
Soft tissues
Distilled water in a squeeze bottle
Stirring rod or spoon
Masking tape
Permanent marker
Latex gloves and safety goggles

Preparation

Condition the pH pen or pH meter probes according to manufacturer's instructions. Remember to allow enough time (> one hour). Often pH pens and probes last longer if they are kept wet. Set up calibration buffer solutions of known pH in class. Calibrate the pen and meter before going to the water site. Bring the tools and materials to the water site, including the buffer solutions.

Prerequisites

None

Background

This Protocol involves determining the pH of the water sample from your Hydrology Study Site. We suggest that beginning level students use pH indicator paper, intermediate level students use a pH pen, and advanced level students use a pH meter.

How To Measure pH

Method 1: pH indicator paper

Beginning Level

1. Rinse a 50 mL or 100 mL beaker at least twice with sample water.
2. Fill the beaker about halfway with water to be tested.
3. Dip one strip of indicator paper into the sample water for at least a minute. Make sure all four segments of the paper are immersed in sample water.
4. Remove the paper from the water and compare the resultant four color segments with the chart on the back of the pH indicator paper box. Try to find a sequence where all four segments on the sample paper match all four segments on the box.
5. If reading is unclear, it may be because the paper needs more time to fully react. The indicator paper takes longer to react in water with conductivities below 400 microSiemens/cm. See the Electrical Conductivity Protocol. If this is the case, place the paper back into the sample for an additional minute, and check again. Repeat until satisfied that the reading is accurate. If the reading is still unclear after 10 minutes, start over with a new strip of pH paper. If the test fails a second time, make this clear on your Hydrology Investigation Data Work Sheet.
6. Read the corresponding pH and record this value on your Hydrology Investigation Data Work Sheet. Report this value to the GLOBE Student Data Server.

Note: pH paper readings may not be accurate if your water sample has an electrical conductivity below 300 microSiemens/cm (pH paper does not function properly below this level). See the *Electrical Conductivity Protocol*.

Method 2: pH pen or pH meter

Intermediate and Advanced Levels

In order to measure the pH of your water sample using the pH meter you need to: (1) prepare buffer solutions, (2) calibrate the instruments, (3) recheck your instrument by measuring the buffers in the field, and (4) measure the pH of your sample in the field.

Calibration Procedure

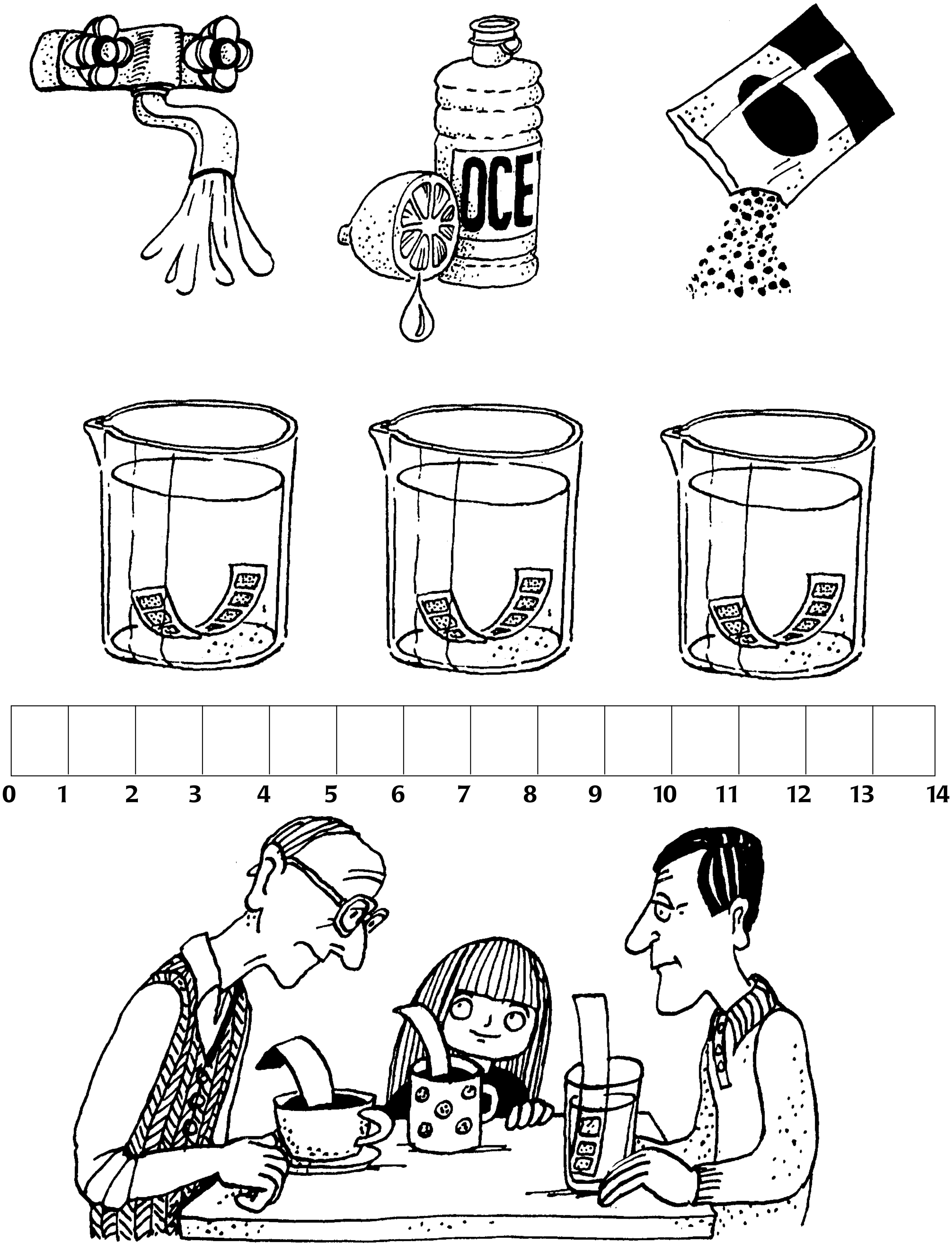
Calibration should be performed before each set of measurements. This procedure can be performed in the classroom before you go out in the field.

Step 1: Prepare the Buffer Solutions

Pre-mixed buffer solutions can be stored for 1 year, as long as they have not been contaminated. If you are using the powdered pillow buffer, then dissolve it in distilled water as described below. If you are using pre-mixed buffer solutions, measure 50 mL into a graduated cylinder and proceed to step 4.

For each pH buffer (4, 7, and 10):

1. Write the buffer pH and date on two pieces of masking tape. Place one on a clean, dry 100 mL beaker and the other on a 50 mL bottle or well cleaned baby food jar.
2. Using a graduated cylinder, measure 50 mL of distilled water and pour it into the beaker.
3. Over the beaker, completely cut open one end of a pillow of buffer powder, then squeeze and shake the pillow to release the powder into the water. Make sure all the powder is released into the water. Stir with stirring rod or spoon until all the powder dissolves.
4. Pour the buffer solution into the labeled bottle. Cap the bottle tightly. Discard after a month.
5. Continue preparing the other buffers, repeating steps 1-4 for each.



Source: Jan Smolík, 1996, TEREZA, Association for Environmental Education, Czech Republic

Step 2: Calibrate the pH pen or meter

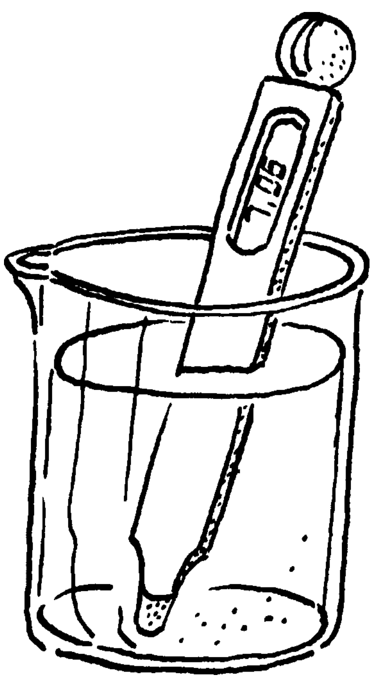
A. Calibration of the pH pen

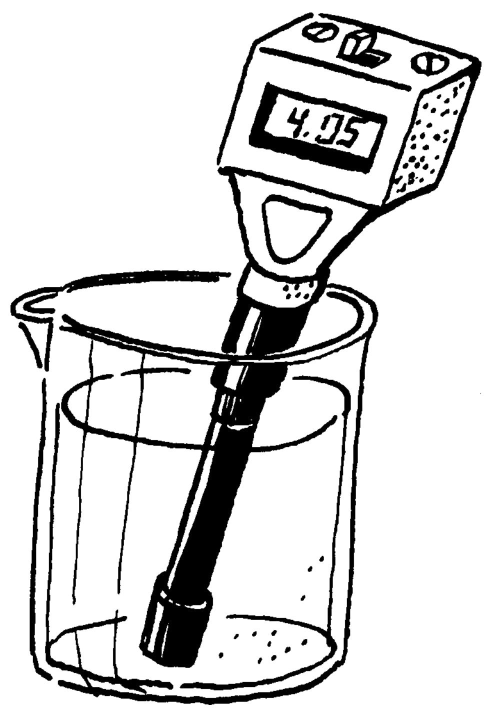
Note: If the pH pen does not have automatic temperature compensation, the buffer solution should be at 25° C.

1. Condition the electrode as described by the manufacturer.
2. Rinse the electrode (glass probe) and area around it twice with distilled water using a squeeze bottle and blot dry with a soft tissue after each rinse. Rinse into a discard beaker or sink, not into the pH buffer solution and do not touch the electrode (glass probe) with your fingers.
3. Turn the pen on with the switch on top, then immerse the electrode entirely in the pH 7.0 buffer solution. See Figure HYD-P-3.
4. Gently stir the buffer solution with the probe and wait for the reading to stabilize.
5. Use a jewelry screwdriver to turn the small screw in the hole in the back of the pen until the reading is exactly 7.0.
6. Remove the pH pen from the solution and rinse the electrode with distilled water; pour the buffer solution back into its labeled bottle and seal tightly.

B. Calibration of the pH meter

1. Condition the electrode (probe) as described in the manufacturer's instructions.
2. Rinse the electrode (glass probe) and area around it twice with distilled water using a squeeze bottle and blot dry with a soft tissue after each rinse. Rinse into a discard beaker or sink, not into the pH buffer solution and do not touch the electrode (glass probe) with your fingers.
3. Turn the meter on (by pressing the ON/OFF button). Push the CAL button to indicate that you will be calibrating the instrument.
4. Immerse the electrode in the pH 7.0 buffer solution, making sure that the electrode is entirely immersed. Do not immerse the instrument further than is necessary. See Figure HYD-P-3.
5. Gently stir the buffer solution with the electrode and wait for the display value to stabilize. Once the reading has stabilized, press the HOLD/CON button to accept the value and complete the calibration. If the electrode is still immersed in the buffer, the





Source: Jan Smolík, 1996, TEREZA, Association for Environmental Education, Czech Republic

display will read the same value as the pH of the buffer (i.e. 4, 7, or 10).
6. Remove the pH tester from the buffer solution, rinse the electrode with distilled water, and blot dry with soft tissue.
7. Repeat steps 3 through 6 using the pH 4 buffer and then using the pH 10 buffer.
8. Set the tester aside on a paper towel; turn the meter off by pushing the ON/OFF button.
9. Pour the buffer solution into their labeled bottles and cap them tightly.

Step 3: Recheck your pH pen or meter in the Field

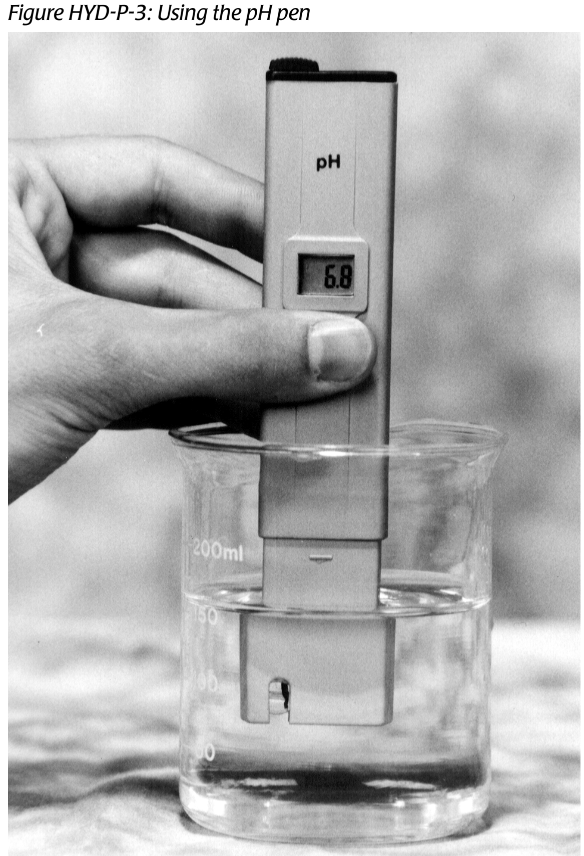
1. Take the pH buffer solutions into the field with you. Treat them as samples. Test the pH of the buffer solutions and record the field pH buffer values on the data sheets. If the values of the buffer solutions are more than + or - 0.2 pH units from the true value, go through the instrument calibration procedure again.
2. After you have tested the pen or meter with the buffer solutions, you are ready to measure the pH of the actual water sample.

pH Measurement Procedure

1. Rinse the electrode and the surrounding area with distilled water using the squeeze bottle. Blot the area dry with a soft tissue.
2. Fill a clean, dry 100 mL beaker to the 50 mL line with the water to be tested.
3. Immerse the electrode in the water. Be sure that the entire electrode is immersed, but avoid immersing it any further than necessary.
4. Stir once and then let the display value stabilize.
5. Once the display value is stable, read the pH value and record it in the Hydrology Investigation Data Work Sheet.
6. Repeat steps 1 through 5 for another sample as a quality control check. The two pH values should agree to within 0.2 which is the accuracy of this technique.
7. Rinse the probe with distilled water, blot it dry with soft tissue, replace the cap on the probe, and turn the instrument off.
8. Take the average of pH values measured by the student groups. If the recorded values are all within 0.2 of the average, report the average value to the GLOBE Student Data Server. If there is one outlier (a value far different from the rest) discard that value and calculate the average of the other values. If they are all now within 0.2 of this new average, report this new average to the GLOBE Student Data Server. If there is a wide scatter in results, discuss the procedure and the potential sources of error with the students, but do not report a value to the Data Server. Repeat the protocol if possible to produce a reportable measurement.

Note: pH pen or meter readings may not be accurate if your water sample has a conductivity below 100 microSiemens/cm (pH pens and meters do not function properly below this level). See the *Electrical Conductivity Protocol*.

Figure HYD-P-3: Using the pH pen



Electrical Conductivity Protocol

Purpose
To measure the conductivity of the water at the Hydrology Study Site

Overview
Conductivity is a measure of the amount of total dissolved solids in the water.

Time
5 minutes

Level
All

Frequency
Weekly including calibration

Key Concepts
Conductivity, factors affecting conductivity
Standardization, calibration
Accuracy, Precision

Skills
Using a conductivity meter
Recording data

Materials and Tools
Total dissolved solids tester (or conductivity tester)
Standard solution
Distilled water
Squeeze bottle
Soft tissue
Three 50 mL or 100 mL beakers
Jewelry screwdriver (for calibration)

Preparation
Perform the *Calibration* procedure below. Bring the tools and materials to the water site.

Prerequisites
None

Note: this measurement is for freshwater only. For salt and brackish waters measure salinity instead.

Background
Conductivity is measured in microSiemens/ centimeter (µS/cm). A microSiemen is the same as a micromho.

Conductivity of a water sample is a measure of its ability to carry an electric current. The more impurities (total dissolved solids) in water, the greater its electrical conductivity. By measuring the conductivity of a water sample, the amount of total dissolved solids in the sample can be determined. To convert the electrical conductivity (microSiemens/cm) of a water sample to the concentration of total dissolved solids (ppm) in the sample, the conductivity must be multiplied by a factor of between 0.54 and 0.96 for natural waters. The value of this factor depends upon the type of dissolved solids. A widely accepted value to use when you are not determining the type of dissolved solids is 0.67.

TDS (ppm) = Conductivity (microSiemens/cm) x 0.67

Calibration
The conductivity meter should be calibrated before each set of measurements. Before use and every six months the temperature compensation should be checked. Calibration standards should be replaced annually.

Calibration
1. The standard solution should be tightly capped and kept refrigerated. The label on the bottle in which the solution is stored should include the date on which the solution was made or purchased.

2. Remove the cap from the meter.
3. Line up two clean and dry 100 mL beakers and fill each beaker with just enough standard solution to immerse the electrode. Note: Other standard solutions are available and acceptable. Please calibrate instrument accordingly.
4. Press the ON/OFF button to turn the tester ON.
5. Rinse the electrode (at the bottom tip of the pen) with distilled water from a squeeze bottle. Do not rinse above the brown line. Blot it dry with a soft tissue.
6. Immerse the electrode in the first beaker of standard solution for a second or two. Take the meter out of the first beaker and dip it into the second standard solution beaker, without rinsing the electrode. See Figure HYD-P-4.
7. Gently stir for a few seconds, then allow the display value to stabilize.
8. If the display does not read the standard value, you must adjust the instrument to read this number. Using a small screwdriver, adjust the calibration screw on the pen until the display reads the standard value. Note: Some conductivity meters may have different adjustments.
9. Discard the standard solution that was used in the two beakers. Do not return the standard solution used in this procedure to its original bottle!
10. Rinse the electrode with distilled water and blot it dry. Rinse the beakers thoroughly.
11. Press the ON/OFF button to turn the meter off. Cap the meter.

Temperature Compensation Check

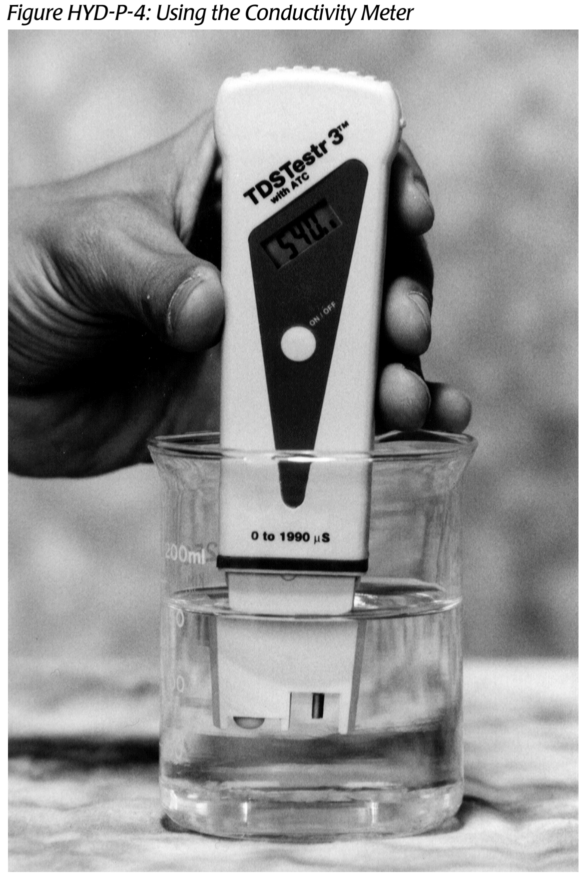
Conductivity measurements are affected by the water sample temperature. Your meter should be temperature compensated to give a conductivity reading equivalent to a temperature of 25° C.

Measure the conductivity of your standard at 5, 15, 25, and 35° C. If the conductivity reading is outside the specified range (+/– 40 µS/cm) for your standard at 25° C, then contact the manufacturer.

Quality Control in the Field

Whether the tester is calibrated in the classroom or in the field, the standard solution must be tested with the following protocol as if it were a water sample. When tested the standard should read its true value. If it does not, the instrument must be recalibrated, and the conductivity measurement made again.

Figure HYD-P-4: Using the Conductivity Meter



How to Measure Conductivity

1. Remove cap from the meter and press the ON/OFF button to turn the tester on.
2. Rinse the electrode with distilled water and blot it dry.
3. Fill a clean, dry, 100 mL beaker with water to be tested.
4. Immerse the electrode in the water sample. See Figure HYD-P-4.
5. Gently stir the sample for a few seconds, then allow the display value to stabilize.
6. Read the display value and record its value on the Hydrology Investigation Data Work Sheet.
7. Take the average of the electrical conductivity values measured by the student groups. If the recorded values are all within 40 microSiemens/cm of the average, report the average value to the GLOBE Student Data Server. If you have more than three groups and there is one outlier (a value far different from the rest), discard that value and calculate the average of the other values. If they are now all within 40 microSiemens/cm of this new average, report this new average to the GLOBE Student Data Server. If there is a wide scatter in results, discuss the procedure and the potential sources of error with the students, but do not report a value to the GLOBE Student Data Server. Repeat the protocol if possible to produce a reportable measurement.

Salinity Protocol

Purpose
To measure the salinity of the water sample using the hydrometer method

Overview
The salt content (salinity) of a water body is one of the main factors determining what organisms will be found there. The density of water is related to the amount of salt dissolved in it. A hydrometer is used to measure density. The salinity of the water is determined from the density and water temperature.

Level
All

Time
Actual measurement time is 10 minutes.

Frequency
Weekly

Key Concepts
High and low tides
Method of measuring salinity by density
Specific gravity
Salinity in water
Standardization
Accuracy
Precision

Skills
Using a hydrometer and thermometer
Reading conversion tables
Designing measurement strategies
Recording data
Interpreting results.

Materials and Tools
Hydrometer
Conversion table
500 mL clear plastic graduated cylinder
Alcohol-filled thermometer
Table salt (NaCl)
Distilled water
Balance
2 1-liter plastic bottles
Masking tape

Preparation
Complete the *Calibration* activities below. Bring the tools and materials to the water site.

Prerequisites
A brief discussion of salinity and its relation to density

Practice by doing calibration

Note: This measurement is for salt and brackish waters only. For fresh waters measure conductivity instead.

Calibration and Quality Control

Standards should be run at least twice each year to verify your technique. Fresh standards should be prepared annually.

Salinity Standards

Salinity standards do not come with the Hydrometer, and need to be prepared as follows:

1. Add water to table salt to make a 35 ppt salinity standard. Use this salinity standard and a blank to test the accuracy of the hydrometer.

35 ppt standard:

1.1. Measure out 17.5 g NaCl (table salt) using an analytical balance. Pour this into a 500 mL graduated cylinder.
1.2. Fill the cylinder to the 500 mL line with distilled water.
1.3. Carefully swirl the solution until all the salt has dissolved.
1.4. Pour the solution into a 1-liter plastic bottle and label with masking tape (include the date).

Blank:

1.5 Measure out 500 mL of distilled water into a 1-liter plastic bottle and label with masking tape.

2. Perform the Protocol to measure the salinity of the standard and the blank. Where it says "sample water" use the standard or the blank.
3. Record the values measured for these standards on the Calibration Data Work Sheet.
4. If the blank gives a non-zero reading, rinse your glassware and graduated cylinder at least 3 times, and repeat the measurement. If still not zero, get a new source of distilled water.
5. If salinity standard is off by more than 2 ppt, prepare a new standard and repeat the measurement.

Times of High and Low Tide

Obtain the times of high and low tide for the location nearest your site for which these are available. The times reported should be for the high or low tide immediately preceding and following the time you take your measurements. Record these times and the place where they occur on your Hydrology Investigation Data Work Sheet and report them with your other data to the GLOBE Student Data Server.

How to Measure Salinity

Note: Before using the thermometer in this protocol, test it for accuracy following the instructions in *Maximum, Minimum, and Current Temperature Protocol* of the *Atmosphere Investigation.*

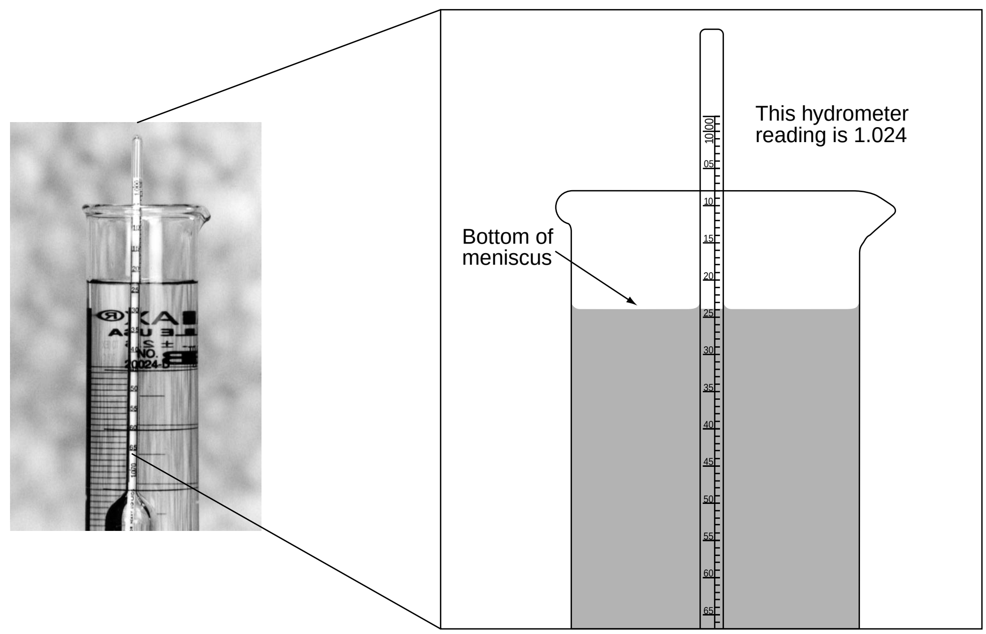
1. Rinse the 500 mL clear plastic graduated cylinder at least twice with sample water.
2. Fill the cylinder with sample water until the water level is 2 to 3 cm from the top of the cylinder.
3. Determine the temperature of your sample following the Water Temperature Protocol and record this value on the Hydrology Investigation Data Work Sheet.
4. Place the hydrometer in the cylinder and allow it to settle. Follow the manufacturer's instructions that came with the hydrometer. The hydrometer should not touch the cylinder walls, and be sure to take the reading from the *bottom* of the meniscus. Read the specific gravity from the hydrometer scale. Reading to three decimal places is acceptable. Older students can practice reading to four decimal places and interpolating between the values given in Table HYD-P-3. Record this value on the Hydrology Investigation Data Work Sheet. See Figure HYD-P-5.
5. Using the temperature and specific gravity values, read the salinity of the sample from Table HYD-P-3. To find the salinity value for your water sample:

   5.1. Look up the temperature and specific gravity of the sample in Table HYD-P-3.

   5.2. Look at the corresponding salinity (ppt) and record it on the Hydrology Investigation Data Work Sheet. For example, a water sample temperature of 22° C and specific gravity of 1.0070 has a salinity of 10.6 ppt.

6. Repeat steps 2 - 5 for at least two additional samples. Different student groups can make these additional measurements.
7. Take the average of the salinity values measured for the different samples. If the recorded values are all within 2 ppt of the average, proceed to step 8. If they are not within 2 ppt of the average, students should repeat the measurement using new samples, then record and average the new values. If there is still one outlier (a value far different from the rest) discard that value, average the remaining values, and if they are now within 2 ppt of this new average, proceed to step 8. If there is still a wide spread in values, discuss the procedures with the students and repeat the measurement if possible.
8. Submit to the GLOBE Student Data Server the temperature, specific gravity, and salinity from the student(s) whose salinity is closest to the average. If only two measurements were used to calculate the average, report the temperature, specific gravity, and salinity from either group.

Figure HYD-P-5: Reading Specific Gravity



Note: Hydrology measurements are read from the bottom of the meniscus.

*Table HYD-P-3: Salinity (parts per thousand) as a function of density and temperature**

	Temperature of Water in Graduated Cylinder (° C)																
Observed Reading	**-2.0**	**-1.0**	**0.0**	**1.0**	**2.0**	**3.0**	**4.0**	**5.0**	**6.0**	**7.0**	**8.0**	**9.0**	**10.0**	**11.0**	**12.0**	**13.0**	**14.0**
0.9980																	
0.9990																	
1.0000																	
1.0010	0.7	0.6	0.6	0.5	0.5	0.2	0.2	0.2	0.2	0.2	0.2	0.5	0.5	0.6	0.6	0.7	0.8
1.0020	2.0	1.9	1.9	1.8	1.6	1.6	1.6	1.5	1.5	1.6	1.6	1.6	1.8	1.9	2.0	2.1	2.3
1.0030	3.3	3.2	3.1	2.9	2.9	2.8	2.8	2.8	2.8	2.8	2.9	2.9	3.1	3.2	3.3	3.4	3.6
1.0040	4.5	4.4	4.2	4.2	4.1	4.1	4.1	4.1	4.1	4.1	4.2	4.2	4.4	4.5	4.6	4.8	4.9
1.0050	5.8	5.7	5.5	5.4	5.4	5.4	5.3	5.3	5.4	5.4	5.4	5.5	5.5	5.7	5.8	5.9	6.2
1.0060	7.0	6.8	6.8	6.7	6.6	6.6	6.6	6.6	6.6	6.7	6.7	6.8	6.8	7.0	7.1	7.2	7.5
1.0070	8.1	8.1	8.0	7.9	7.9	7.9	7.9	7.9	7.9	7.9	8.0	8.1	8.1	8.3	8.4	8.5	8.8
1.0080	9.4	9.3	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.3	9.3	9.4	9.6	9.7	9.8	10.0
1.0090	10.6	10.5	10.5	10.4	10.4	10.4	10.4	10.4	10.5	10.5	10.6	10.6	10.7	10.9	11.0	11.1	11.3
1.0100	11.9	11.8	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.8	11.8	11.9	12.0	12.2	12.3	12.4	12.6
1.0110	13.1	13.0	13.0	12.8	12.8	12.8	12.8	13.0	13.0	13.1	13.1	13.2	13.4	13.5	13.6	13.7	13.9
1.0120	14.3	14.3	14.1	14.1	14.1	14.1	14.1	14.1	14.3	14.3	14.4	14.5	14.7	14.8	14.9	15.0	15.2
1.0130	15.6	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.4	15.6	15.7	15.8	15.8	16.0	16.2	16.3	16.5
1.0140	16.7	16.7	16.6	16.6	16.6	16.6	16.6	16.7	16.7	16.9	17.0	17.0	17.1	17.3	17.5	17.7	17.8
1.0150	18.0	17.9	17.9	17.9	17.9	17.9	17.9	17.9	18.0	18.0	18.2	18.3	18.4	18.6	18.8	19.0	19.1
1.0160	19.2	19.2	19.1	19.1	19.1	19.1	19.2	19.2	19.3	19.3	19.5	19.6	19.7	19.9	20.1	20.3	20.4
1.0170	20.4	20.4	20.4	20.4	20.4	20.4	20.4	20.5	20.5	20.6	20.8	20.9	21.0	21.2	21.3	21.6	21.7
1.0180	21.7	21.7	21.7	21.6	21.6	21.7	21.7	21.7	21.8	22.0	22.1	22.2	22.3	22.5	22.6	22.9	23.0
1.0190	22.9	22.9	22.9	22.9	22.9	22.9	23.0	23.0	23.1	23.3	23.4	23.5	23.6	23.8	23.9	24.2	24.3
1.0200	24.2	24.2	24.2	24.0	24.2	24.2	24.2	24.3	24.3	24.4	24.6	24.7	24.8	25.1	25.2	25.5	25.6
1.0210	25.3	25.3	25.3	25.3	25.3	25.5	25.5	25.6	25.6	25.7	25.9	26.0	26.1	26.4	26.5	26.8	26.9
1.0220	26.6	26.6	26.6	26.6	26.6	26.6	26.8	26.8	26.9	27.0	27.2	27.3	27.4	27.7	27.8	28.1	28.2
1.0230	27.8	27.8	27.8	27.8	27.8	27.9	27.9	28.1	28.2	28.3	28.5	28.6	28.7	28.9	29.1	29.4	29.5
1.0240	29.1	29.1	29.1	29.1	29.1	29.1	29.2	29.4	29.5	29.5	29.8	29.9	30.0	30.2	30.4	30.6	30.8
1.0250	30.3	30.3	30.3	30.3	30.4	30.4	30.6	30.6	30.7	30.8	30.9	31.1	31.3	31.5	31.7	31.9	32.1
1.0260	31.6	31.6	31.6	31.6	31.6	31.7	31.7	31.9	32.0	32.1	32.2	32.4	32.6	32.8	33.0	33.2	33.4
1.0270	32.8	32.8	32.8	32.9	32.9	32.9	33.0	33.2	33.3	33.4	33.5	33.7	33.9	34.1	34.3	34.5	34.7
1.0280	33.9	34.1	34.1	34.1	34.1	34.2	34.3	34.5	34.5	34.7	34.8	35.0	35.1	35.4	35.6	35.8	36.0
1.0290	35.2	35.2	35.2	35.4	35.4	35.5	35.5	35.6	35.8	35.9	36.2	36.3	36.4	36.7	36.8	37.1	37.3
1.0300	36.4	36.5	36.5	36.5	36.7	36.7	36.8	36.9	37.1	37.2	37.3	37.6	37.7	38.0	38.1	38.4	38.6
1.0310	37.7	37.7	37.7	37.8	37.8	38.0	38.1	38.2	38.4	38.5	38.6	38.9	39.0	39.3	39.4	39.7	39.9

* Adapted from LaMotte hydrometer instructions.

Table HYD-P-3: Salinity (parts per thousand) as a function of density and temperature - continued

	Temperature of Water in Graduated Cylinder (° C)																
Observed Reading	**15.0**	**16.0**	**17.0**	**18.0**	**18.5**	**19.0**	**19.5**	**20.0**	**20.5**	**21.0**	**21.5**	**22.0**	**22.5**	**23.0**	**23.5**	**24.0**	**24.5**
0.9980																	
0.9990										0.0	0.1	0.2	0.3	0.5	0.6	0.7	
1.0000		0.0	0.2	0.3	0.5	0.6	0.7	0.8	1.0	1.1	1.2	1.4	1.5	1.6	1.8	1.9	2.0
1.0010	1.0	1.2	1.5	1.6	1.8	1.9	2.0	2.1	2.3	2.4	2.5	2.5	2.7	2.8	2.9	3.1	3.2
1.0020	2.4	2.5	2.8	2.9	3.1	3.2	3.3	3.4	3.6	3.7	3.8	4.0	4.1	4.2	4.4	4.6	4.8
1.0030	3.7	3.8	4.1	4.2	4.4	4.5	4.6	4.8	4.9	5.0	5.1	5.3	5.4	5.5	5.8	5.9	6.1
1.0040	5.0	5.1	5.4	5.5	5.7	5.8	5.9	6.1	6.2	6.3	6.4	6.6	6.7	7.0	7.1	7.2	7.4
1.0050	6.3	6.6	6.7	7.0	7.1	7.1	7.2	7.4	7.5	7.6	7.7	7.9	8.1	8.3	8.4	8.5	8.7
1.0060	7.6	7.9	8.0	8.3	8.4	8.5	8.7	8.8	8.9	9.1	9.2	9.3	9.4	9.6	9.7	9.8	10.1
1.0070	8.9	9.2	9.3	9.6	9.7	9.8	10.0	10.1	10.2	10.4	10.5	10.6	10.7	10.9	11.0	11.3	11.4
1.0080	10.2	10.5	10.6	10.9	11.0	11.1	11.3	11.4	11.5	11.7	11.8	11.9	12.0	12.2	12.4	12.6	12.7
1.0090	11.5	11.8	11.9	12.2	12.3	12.4	12.6	12.7	12.8	13.0	13.1	13.2	13.4	13.6	13.7	13.9	14.0
1.0100	12.8	13.1	13.2	13.5	13.6	13.7	13.9	14.0	14.1	14.3	14.4	14.5	14.8	14.9	15.0	15.2	15.3
1.0110	14.1	14.4	14.5	14.8	14.9	15.0	15.2	15.3	15.4	15.6	15.7	16.0	16.1	16.2	16.3	16.5	16.7
1.0120	15.4	15.7	15.8	16.1	16.2	16.3	16.5	16.6	16.7	17.0	17.1	17.3	17.4	17.5	17.7	17.9	18.0
1.0130	16.7	17.0	17.1	17.4	17.5	17.7	17.8	17.9	18.0	18.3	18.4	18.6	18.7	18.8	19.1	19.2	19.3
1.0140	18.0	18.3	18.6	18.7	18.8	19.0	19.1	19.3	19.5	19.6	19.7	19.9	20.0	20.1	20.4	20.5	20.6
1.0150	19.3	19.6	19.9	20.0	20.1	20.4	20.5	20.6	20.8	20.9	21.0	21.2	21.3	21.6	21.7	21.8	22.0
1.0160	20.6	20.9	21.2	21.3	21.4	21.7	21.8	22.0	22.1	22.2	22.3	22.5	22.7	22.9	23.0	23.3	23.4
1.0170	22.0	22.2	22.5	22.7	22.9	23.0	23.1	23.3	23.4	23.5	23.6	23.8	24.0	24.2	24.3	24.6	24.7
1.0180	23.3	23.5	23.8	24.0	24.2	24.3	24.4	24.6	24.7	24.8	24.9	25.2	25.3	25.5	25.6	25.9	26.0
1.0190	24.6	24.8	25.1	25.3	25.5	25.6	25.7	25.9	26.0	26.1	26.4	26.5	26.6	26.8	27.0	27.2	27.3
1.0200	25.9	26.1	26.4	26.6	26.8	26.9	27.0	27.2	27.3	27.4	27.7	27.8	27.9	28.2	28.3	28.5	28.6
1.0210	27.2	27.4	27.7	27.9	28.1	28.2	28.3	28.5	28.6	28.9	29.0	29.1	29.2	29.5	29.6	29.8	30.0
1.0220	28.5	28.7	29.0	29.2	29.4	29.5	29.6	29.8	30.0	30.2	30.3	30.4	30.7	30.8	30.9	31.2	31.3
1.0230	29.8	30.0	30.3	30.6	30.7	30.8	30.9	31.2	31.3	31.5	31.6	31.7	32.0	32.1	32.2	32.5	32.6
1.0240	31.1	31.3	31.6	31.9	32.0	32.1	32.2	32.5	32.6	32.8	32.9	33.2	33.3	33.4	33.7	33.8	33.9
1.0250	32.4	32.6	32.9	33.2	33.3	33.4	33.7	33.8	33.9	34.1	34.2	34.5	34.6	34.7	35.0	35.1	35.2
1.0260	33.7	33.9	34.2	34.5	34.6	34.7	35.0	35.1	35.2	35.4	35.6	35.8	35.9	36.0	36.3	36.4	36.7
1.0270	35.0	35.2	35.5	35.8	35.9	36.2	36.3	36.4	36.5	36.7	36.9	37.1	37.2	37.5	37.6	37.8	38.0
1.0280	36.3	36.5	36.8	37.1	37.2	37.5	37.6	37.7	37.8	38.1	38.2	38.4	38.5	38.8	38.9	39.1	39.3
1.0290	37.6	37.8	38.1	38.4	38.6	38.8	38.9	39.0	39.1	39.4	39.5	39.7	39.9	40.1	40.2	40.5	40.6
1.0300	38.9	39.1	39.4	39.7	39.9	40.1	40.2	40.3	40.6	40.7	40.8	41.0	41.2	41.4	41.6	41.8	41.9
1.0310	40.2	40.5	40.7	41.0	41.2	41.4	41.5	41.8	41.9	42.0	42.1	42.3	42.5				

Table HYD-P-3: Salinity (parts per thousand) as a function of density and temperature - continued

	Temperature of Water in Graduated Cylinder (° C)																
Observed Reading	**25.0**	**25.5**	**26.0**	**26.5**	**27.0**	**27.5**	**28.0**	**28.5**	**29.0**	**29.5**	**30.0**	**30.5**	**31.0**	**31.5**	**32.0**	**32.5**	**33.0**
0.9980			0.1	0.2	0.3	0.6	0.7	0.8	1.1	1.2	1.5	1.6	1.9	2.0	2.3	2.4	
0.9990	0.8	1.0	1.2	1.4	1.5	1.8	1.9	2.0	2.3	2.4	2.5	2.8	2.9	3.2	3.4	3.6	3.8
1.0000	2.1	2.4	2.5	2.7	2.9	3.1	3.2	3.4	3.6	3.7	4.0	4.1	4.4	4.5	4.8	4.9	5.1
1.0010	3.4	3.6	3.8	4.0	4.2	4.4	4.5	4.8	4.9	5.1	5.1	5.4	5.5	5.8	5.9	6.2	6.4
1.0020	4.9	5.0	5.1	5.4	5.5	5.7	5.9	6.1	6.3	6.4	6.6	6.8	7.0	7.2	7.5	7.6	7.9
1.0030	6.2	6.3	6.6	6.7	6.8	7.1	7.2	7.4	7.6	7.7	8.0	8.1	8.4	8.5	8.8	9.1	9.2
1.0040	7.5	7.7	7.9	8.0	8.3	8.4	8.5	8.8	8.9	9.2	9.3	9.6	9.7	10.0	10.1	10.4	10.5
1.0050	8.9	9.1	9.2	9.3	9.6	9.7	10.0	10.1	10.2	10.5	10.6	10.9	11.0	11.3	11.5	11.7	11.9
1.0060	10.2	10.4	10.5	10.7	10.9	11.0	11.3	11.4	11.7	11.8	12.0	12.2	12.4	12.6	12.8	13.1	13.2
1.0070	11.5	11.7	11.9	12.0	12.2	12.4	12.6	12.8	13.0	13.1	13.4	13.6	13.7	14.0	14.1	14.4	14.7
1.0080	12.8	13.0	13.2	13.4	13.6	13.7	13.9	14.1	14.3	14.5	14.7	14.9	15.2	15.3	15.6	15.7	16.0
1.0090	14.1	14.4	14.5	14.7	14.9	15.0	15.3	15.4	15.7	15.8	16.1	16.2	16.5	16.6	16.9	17.1	17.3
1.0100	15.6	15.7	15.8	16.1	16.2	16.5	16.6	16.7	17.0	17.1	17.4	17.5	17.8	18.0	18.2	18.4	18.7
1.0110	16.9	17.0	17.3	17.4	17.5	17.8	17.9	18.2	18.3	18.6	18.7	19.0	19.1	19.3	19.6	19.7	20.0
1.0120	18.2	18.3	18.6	18.7	19.0	19.1	19.3	19.5	19.6	19.9	20.1	20.3	20.5	20.6	20.9	21.2	21.3
1.0130	19.5	19.7	19.9	20.0	20.3	20.4	20.6	20.8	21.0	21.2	21.4	21.6	21.8	22.1	22.2	22.5	22.7
1.0140	20.9	21.0	21.2	21.4	21.6	21.8	22.0	22.2	22.3	22.6	22.7	23.0	23.1	23.4	23.6	23.8	24.0
1.0150	22.2	22.3	22.5	22.7	22.9	23.1	23.3	23.5	23.6	23.9	24.0	24.3	24.6	24.7	24.9	25.2	25.3
1.0160	23.5	23.6	23.9	24.0	24.3	24.4	24.7	24.8	25.1	25.2	25.5	25.6	25.9	26.1	26.3	26.5	26.8
1.0170	24.8	25.1	25.2	25.3	25.6	25.7	26.0	26.1	26.4	26.5	26.8	27.0	27.2	27.4	27.7	27.8	28.1
1.0180	26.1	26.4	26.5	26.8	26.9	27.2	27.3	27.6	27.7	27.9	28.1	28.3	28.5	28.7	29.0	29.2	29.4
1.0190	27.6	27.7	27.8	28.1	28.2	28.5	28.6	28.9	29.0	29.2	29.5	29.6	29.9	30.0	30.3	30.6	30.8
1.0200	28.9	29.0	29.2	29.4	29.6	29.8	30.0	30.2	30.4	30.6	30.8	30.9	31.2	31.5	31.6	31.9	32.1
1.0210	30.2	30.3	30.6	30.7	30.9	31.1	31.3	31.5	31.7	32.0	32.1	32.4	32.5	32.8	33.0	33.3	33.4
1.0220	31.5	31.7	31.9	32.0	32.2	32.5	32.6	32.9	33.0	33.3	33.4	33.7	33.9	34.1	34.3	34.6	34.8
1.0230	32.8	33.0	33.2	33.4	33.5	33.8	33.9	34.2	34.5	34.6	34.8	35.0	35.2	35.5	35.6	35.9	36.2
1.0240	34.2	34.3	34.5	34.7	35.0	35.1	35.4	35.5	35.8	35.9	36.2	36.4	36.5	36.8	37.1	37.2	37.5
1.0250	35.5	35.6	35.9	36.0	36.3	36.4	36.7	36.8	37.1	37.2	37.5	37.7	37.8	38.1	38.4	38.6	38.8
1.0260	36.8	36.9	37.2	37.3	37.6	37.7	38.0	38.2	38.4	38.6	38.8	39.0	39.3	39.4	39.7	39.9	40.2
1.0270	38.1	38.4	38.5	38.8	38.9	39.1	39.3	39.5	39.8	39.9	40.2	40.3	40.6	40.8	41.0	41.2	41.5
1.0280	39.4	39.7	39.8	40.1	40.2	40.5	40.7	40.8	41.1	41.2	41.5						
1.0290	40.8	41.0	41.2	41.4	41.6	41.8											

Optional Salinity Titration Protocol

Purpose

To measure the salinity of the water sample using the more accurate salinity titration method

Overview

The major dissolved constituents (salts) in sea water are found in relatively constant proportions. By measuring the concentration of any one of them in sea water samples, in this case chloride (chlorinity), the water sample's salinity can then be inferred.

Level

Intermediate, Advanced

Time

10-15 minutes

Frequency

Weekly

Calibration every six months

Key Concepts

Method of measuring salinity using the concentration of one chemical constituent of sea water
Constancy of sea water composition
Standardization
Accuracy
Salinity in water
High and low tides
Precision

Skills

Using the salinity titration test procedure
Designing measurements strategies
Recording data
Interpreting results

Materials and Tools

Salinity Titration Test Kit (See Toolkit)
Data Work Sheets
Latex gloves
1-liter plastic bottle
Table salt
Distilled water
Masking tape
500 mL clear plastic graduated cylinder
Balance

Preparation

Complete the *Calibration* activities below.

Prerequisites

A brief discussion of the relation of salinity to chlorinity and how titration is used to measure them

Practice by doing calibration.

Note: This measurement is for salt and brackish waters only. For fresh waters measure conductivity instead.

Note: For background information and special considerations for brackish and salty water Hydrology Study Sites, please refer to those sections of the *Salinity Protocol*.

Calibration and Quality Control

Calibration should be performed at least every six months to verify your technique and the integrity of your chemicals. Fresh standards should be prepared annually.

Salinity Standards

Salinity standards do not come with the Salinity Titration Kit, and one needs to be prepared as follows:

1. Add water to table salt to make a sea water titration standard of 38.6 ppt salinity. Use this standard to test the accuracy of the Salinity Titration Test Kit.
   1.1. Measure out 17.5 g NaCl (table salt) using an analytical balance. Pour this into a 500 mL graduated cylinder.
   1.2. Fill the cylinder to the line with distilled water.
   1.3. Carefully swirl the solution to mix the standard.
   1.4. Pour the solution into a 1-liter plastic bottle and label with masking tape (include the date).
2. Follow directions in the Protocol section to measure the standards. Where it says "sample water" use the standard that you made.
3. Record the value of the standards after testing on the Hydrology Investigation Data Work Sheet.
4. If salinity standards are off by more than 0.4 ppt, prepare new standards and repeat the measurement.

Note: The sea water titration standard concentration is corrected for sea water composition. For example, to calculate the sea water salinity from 17.5 g NaCl in 500 mL (35 ppt NaCl), take into account the molecular composition of NaCl (the ratio of the molecular weight of Cl to NaCl is 0.61): 35 ppt x 0.61 = 21.35 ppt chlorinity. The salinity of the standard is 21.35 x 1.80655 = 38.6 ppt because in sea water chloride ions comprise 55.354% of the total dissolved salts by weight.

Times of High and Low Tide

Obtain the times of high and low tide for the location nearest your site for which these are available. The times reported should be for the high or low tide immediately preceding and following the time you make your measurements. Record these times and place they occur on your Hydrology Investigation Data Work Sheet and report them with your other data to the GLOBE Student Data Server.

How to Measure Salinity

1. Use a salinity titration test kit which meets the *Globe Instruments Specifications* in the *Toolkit*. The kits are based on the technique of adding a color indicator to the sample and then adding an acid titrant dropwise until a color change is observed.
2. Follow the manufacturer's instructions on the kit. To titrate more saline water than 20 parts per thousand (ppt), refill the titrator with acid, keeping a record of the total amount of acid used.
3. Record the salinity in ppt on the Hydrology Investigation Data Work Sheet.
4. Take the average of the salinity values measured by the student groups. If the recorded values are all within 0.4 ppt of the average, submit the average to the GLOBE Student Data Server. If they are not within 0.4 ppt of the average have the students retitrate the sample, then record and average the new values. If there is still one outlier (a value far different from the rest) discard that value and average the rest of the values. If they are now all within 0.4 ppt of the new average, report this new average to the GLOBE Student Data Server. If there is a wide scatter (more than 0.4 ppt) in results, discuss the procedure and the potential sources of error with the students, but do not report a value to the Data Server. Repeat the protocol to produce a reportable measurement.
5. Put all liquids in waste bottles.

Alkalinity Protocol

Purpose

To measure the alkalinity of the water sample

Overview

Alkalinity is closely related to the kinds of aquatic life that will survive in water.

Time

15 minutes

Level

Intermediate, Advanced

Frequency

Weekly

Calibration every six months

Key Concepts

Alkalinity, natural factors affecting alkalinity
Method of measurement of alkalinity
Standardization
Accuracy, Precision

Skills

Using the alkalinity test procedure properly
Recording data

Materials and Tools

Alkalinity Test Kit (See *Toolkit*)
Baking soda (sodium bicarbonate)
Distilled water bottle
Distilled water
500 mL beaker
100 mL graduated cylinder
500 mL graduated cylinder
Stirring rod
Data sheets
Sample bottle
Latex gloves/safety goggles
Balance

Preparation

Complete the Calibration/Quality Control activities below. Bring the tools and materials to the water site.

Prerequisites

None

Calibration and Quality Control

Preparing the Baking Soda Standard

1. Using your balance, weigh out 1.9 g baking soda and add it to your 500 mL graduated cylinder. Make sure to transfer all of the baking soda to the cylinder.
2. Fill the 500 mL graduated cylinder to the 500 mL mark with distilled water.
3. Pour this solution into the 500 mL beaker, and stir it with a stirring rod to make sure all of the baking soda has dissolved.
4. Pour 15 mL from the beaker into the 100 mL graduated cylinder.
5. Rinse the 500 mL graduated cylinder with distilled water first. Pour the 15 mL of your baking soda solution into the 500 mL graduated cylinder.
6. Fill the 500 mL graduated cylinder to the 500 mL mark with distilled water.
7. The solution in your 500 mL graduated cylinder is your standard.

The true alkalinity of this baking soda standard is 68 mg/L as $CaCO_3$. The true value for distilled water is usually below 14 mg/L.

Quality Control Procedure

1. Do the alkalinity protocol below using the baking soda standard instead of your water sample.
2. Record the alkalinity value in mg/L as $CaCO_3$ on the Calibration Data Work Sheet.

If the baking soda standard is off by more than the mg/L equivalent of one drop or one gradation of the titrator for your alkalinity kit, prepare a new baking soda standard making sure your weights and dilutions are accurate. If you are still off by more than the mg/L equivalent of one drop or one gradation of the titrator for your alkalinity kit, you may need to get new reagents for your kit.

How to Measure Alkalinity

If your alkalinity kit has both a low range protocol and a high range protocol, use the low range protocol unless your water sample has an alkalinity greater than about 125 mg/L as $CaCO_3$. This will enable you to make more precise measurements.

1. Use an alkalinity test kit which meets the *GLOBE Instruments Specifications* in the *Toolkit*. Follow the manufacturer's instructions. The kits are based on the technique of adding a color indicator to the sample and then adding an acid titrant dropwise until a color change is observed.
2. Record the total alkalinity in mg/L as $CaCO_3$ on the Hydrology Investigation Data Work Sheet.
3. Take the average of the alkalinity values measured by the student groups. If the recorded values are all within the equivalent in mg/L of one drop or one gradation of the titrator for your test kit of the average, report the average value to the GLOBE Student Data Server. If you have more than three groups and there is one outlier (a value far different from the rest) discard that value and calculate the average of the other values. If they are now all within the equivalent in mg/L of one drop or one gradation of the titrator for your test kit of this new average, report this new average to the GLOBE Student Data Server. If there is a wide scatter (more than the equivalent of one drop or one gradation of the titrator) in results, discuss the procedure and the potential sources of error with the students, but do not report a value to the Data Server. Repeat the protocol to produce a reportable measurement.

Nitrate Protocol

Purpose
To obtain nitrate nitrogen measurements of the water at the Hydrology Study Site

Overview
Measuring nitrate levels in water is an important step in the determination of water quality. Nitrogen exists in water in numerous forms, two of which are nitrate (NO_3^-) and nitrite (NO_2^-). Of these forms, nitrate is usually the most important. Nitrite can be found in suboxic waters. Nitrate is an essential nutrient for growth of algae and other aquatic plants, and can be present at high levels due to inputs from a variety of sources. Nitrate is very difficult to measure directly, so it is reduced to nitrite and the resulting nitrite concentration is measured. The measurement gives the combined concentration of nitrite (if present) and nitrate concentrations. Because we are interested in the nitrate measurement, background levels of nitrite also have to be measured. Nitrate measurements are reported as nitrate nitrogen (mg/L). Nitrite measurements are reported as nitrite nitrogen (mg/L).

Level
Intermediate and Advanced

Time
About 15 minutes

Frequency
Weekly

Calibration every six months

Key Concepts
Colorimetric methods for water analysis
Nitrate in water

Skills
Doing a colorimetric analysis
Designing measurement strategies
Recording data

Materials and Tools
50 mL beaker or flask
Nitrate Test Kit (if you have salt or brackish water, be sure to use an appropriate test kit)
100 mL graduated cylinder
500 mL graduated cylinder
3 500-mL bottles or jars
Distilled water

Preparation
Read all instructions carefully in the test kit before beginning. Make sure kit includes all the materials listed. Review proper levels of nitrate that are acceptable in water (10 mg/L nitrate-nitrogen for drinking water).

Prerequisites
A brief discussion of why nitrate is important in water

A discussion of the difference between nitrate nitrogen and nitrate

A discussion of the difference between nitrate and nitrite

Practice by doing calibration.

Calibration and Quality Control

Standards should be run at least every six months to verify your technique and the integrity of your chemicals. Fresh standard should be prepared each time unless the standard has been stabilized. Measuring the standards will help to clarify the instructions in test kits where wording may be unclear.

Nitrate Standards

Nitrate standards do not come with test kits and need to be either ordered separately or prepared as follows:

- **Stock Nitrate Solution:** Dry KNO_3 (potassium nitrate) in an oven for 24 hours at 105° C. Then dissolve 3.6 g of KNO_3 in distilled water. Dilute to 500 mL in your 500 mL graduated cylinder using distilled water. Carefully swirl the solution to mix (do not shake). Store in a 500 ml bottle or jar. Label with masking tape (include date). This makes a 7200 mg/L KNO_3 (or a 1000 mg/L nitrate nitrogen) solution.

  Note: To calculate nitrate nitrogen ($N0_3$-N), take into account the molecular composition of KNO_3 (the ratio of the molecular weight of N to KNO_3 is 0.138): 7200 mg/L KNO_3 x 0.138 ≅ 1000 mg/L nitrate nitrogen ($N0_3$-N).
- **Standard Nitrate Solution:** Measure 50 mL of the stock nitrate solution using the 100 mL graduated cylinder. Pour into the 500 mL graduated cylinder and dilute to 500 mL with distilled water. Carefully swirl the solution to mix. The result is a 100 mg/L nitrate nitrogen standard. Store in a 500 ml bottle or jar. Label with masking tape (include date).
- Make a new stock nitrate solution each time a calibration is conducted if the stock solution has not been preserved. Standard nitrate solutions should be made fresh each time regardless of whether the stock solution has been preserved or not. The stock nitrate solution can be preserved and stabilized for up to six months using chloroform ($CHCl_3$) if you have safe access to this chemical. To preserve a stock nitrate standard add 1 mL of $CHCl_3$ to 500 mL of stock solution.

Quality Control Procedure

1. Dilute the 100 mg/L standard to make a 2 mg/L standard. Use this standard to test the accuracy of the nitrate kit. Measure out 10 mL of the 100 mg/L standard nitrate solution using the 100 mL graduated cylinder. Pour this into the 500 mL flask or beaker. Measure out 490 mL of distilled water in the 500 mL graduated cylinder and add to 500 mL bottle or jar. Label with masking tape (include date). Carefully swirl the solution to mix the standard.
2. Follow the directions in the *Protocol* section to measure the standard. Where it says “sample water” this is where you use the standard that you made.
3. Record the value of the standard after testing on the Hydrology Investigation Data Work Sheet.
4. If the nitrate standard is off by more than 1 mg/L, prepare new dilutions and repeat the measurement. If still off, make a new stock solution and repeat the procedure.

How to Measure Nitrate Nitrogen

1. Use a nitrate measurement kit that meets the *GLOBE Instrument Specifications* in the *Toolkit*. Rinse the sample tubes in the kit at least 3 times with sample water before starting the measurement.
2. **Nitrate nitrogen plus nitrite nitrogen:** Follow the manufacturer’s nitrate instructions in the kit. The kits are based on the technique of adding a reagent that reacts with nitrate to form nitrite. The nitrite reacts with a second reagent to form a color. The intensity of the color is proportional to the amount of nitrate in the sample. The concentration is determined by comparing the sample color, after addition of reagents, to a color comparator included in the kit. If the kit calls for shaking the sample, be sure to shake for the specified period of time.

Failure to follow the times specified in the directions will result in inaccurate measurements.

3. Have at least 3 students in the group read the color comparator. Record the nitrate concentration for each student group on the Hydrology Investigation Data Work Sheet. (**Note:** Hold the comparator up to a light source such as a window, the sky or a lamp. Do not hold it up to the sun.)
4. Take the average of the three readings. If the recorded values are all within 1 mg/L of the average, record the average on the Hydrology Investigation Data Work Sheet. If they are not within 1 mg/L of the average have the students reread the color comparator, then record and average the new values. (**Note:** do not reread if more than 5 minutes has elapsed.) If your remaining values are now all within 1 mg/L of the new average, record this new average on the Hydrology Investigation Data Work Sheet. If there is still one outlier (a value far different from the rest) discard that value and calculate a new average of the other values. If there is still wide scatter (more than 1 mg/L) in results, discuss the procedure and the potential sources of error with the students, but do not report a value to the Data Server. Repeat the protocol to produce a reportable measurement.
5. **Nitrite nitrogen:** Follow the manufacturer's instructions for nitrite. It is the same procedure, except the reagent to reduce nitrate to nitrite is not used.
6. Repeat steps 3 and 4 to obtain nitrite values.

Note: Test results should be reported as mg/L nitrate nitrogen (NO_3- N; the same units as your standards), and not as mg/L nitrate (NO_3^-).

For general information: To convert mg/L nitrate to mg/L nitrate nitrogen divide by 4.4, the ratio of their molecular weights. For example: 44 mg/L NO_3^- is equivalent to 10 mg/L NO_3-N. To convert mg/L nitrite to mg/L nitrite nitrogen divide by 3.3, the ratio of their molecular weights.

Learning Activities

Water Walk

Students become acquainted with their Hydrology Study Site and profile its characteristics.

Model Your Watershed

Students will combine their own local observations with a topographic map and satellite-derived imagery to construct a three-dimensional model of their watershed.

Water Detectives: (K-3)

Students will investigate how they use their senses for observation and why we use instruments to collect data.

pH Game

Students will play a game to better understand the importance of pH levels.

Practicing the Protocols

In the classroom, students practice using the instruments or kits for protocols, exploring the range of measurements and sources of variation and error.

Water,Water Everywhere. How Does it Compare?

Students will begin to look at and analyze GLOBE data with the Hydrology scientists.

Macroinvertebrate Discovery

Students will explore how the water chemistry affects life at their site.

Modeling Your Water Balance

Students will model the changes in soil water storage over a year.

Water Walk

Purpose

To become familiar with the hydrology of your locale

Overview

Students will visit the Hydrology Study Site, conduct a visual survey to discover information about local land use and water quality, and document their findings by mapping and profiling the water body. They will use this initial investigation to raise questions about local land use and/or water chemistry issues that may require further study.

Time

Field trip time plus one class period

Skill Level

All

Key Concepts

Surface water exists in many forms, such as: ponds, lakes, rivers, and snow cover.
Water characteristics are closely related to the characteristics of the surrounding land.
Water moves from one location to another.
Surface water has many observable characteristics, such as: color, smell, flow, and shape.

Skills

Observing water at the study site
Describing water at the study site
Organizing observations
Asking questions based on observations at the study site
Identifying relationships between land characteristics and water characteristics
Communicating initial observations and interpretations orally, in writing and graphically
Mapping the hydrology of the study site

Materials and Tools

Drawing materials and tools for creating pictures and maps
GLOBE Science Notebooks and pens
Still or video cameras for photography
Compass and measuring sticks or twine
Clear plastic cups or bottles for observing the clarity and color of the water

Preparation

Obtain topographic maps and satellite imagery of your study site.

Prerequisites

None

Background

Your body of water is part of a catchment basin. A watershed delineates a catchment basin, the area drained by a river and its tributaries. The topography of the area determines the shape of the watershed. The surrounding land and the uses of this land – towns, cities, highways, agricultural, livestock, timber harvesting, natural vegetation, etc.– influences the water chemistry of bodies of water within the watershed.

Many factors can affect the characteristics of the water in a river system, lake, or pond. Characteristics of water include: temperature, color, shape, etc. In the protocol, you will be collecting data about water quality as measured by dissolved oxygen, pH, alkalinity and electrical conductivity. Field observations increase the students' ability to conceptualize links between land characteristics and water characteristics. This activity is an introduction to your hydrology study site and lays the foundation for subsequent hydrology learning activities and the hydrology protocols.

What To Do and How To Do It

1. Ask students about their knowledge of local bodies of water. Begin with questions such as:
   Is there a lake, river, pond or stream that you visit?
   What is your favorite past-time at this place?
   Why is this body of water important to you?
2. Take your students to the Hydrology Study Site. Remind them of safety issues.

For beginning levels:

3. For the younger students, the goal is to have the students walk around, observe and ask questions about the water in their study site. This includes noticing the flow of rivers or streams, the presence of ponds or lakes, residual water from precipitation, springs and soil moisture. Encourage your students to focus on water in all its forms as they walk around the study site. Take a container and collect a sample of the water. Ask students to observe the color of the water, what they see in the water, whether the water is moving and how fast, what is near the water, whether they can hear the water while they are quiet, whether the water has a smell, whether the water is clear or cloudy, etc.
4. Have your students draw pictures and/or take notes about the location and size of the study site. Compare the water location to other features on their study site such as trees, hills, etc. Have your students ask questions about where the water came from.

For intermediate and advanced levels:

3. Assign teams of students to survey different sections of the site. In teams composed of a journalist, a mapper, a sketcher, and a photographer, students should begin to document what they observe about their section. What is the appearance, smell, nature of the water in their section? Bordering lands should be noted: urban, agricultural, industrial, residential, wooded, swamp, etc. Students should map the general contours and characteristics of their sections and record the wildlife and plants in and around its water. What is the slope of the land adjacent to their section of water?
4. Back in the classroom, students should create a composite display of all the maps. Look for similarities and differences and discuss observed patterns. Based on their observations, encourage students to think about how the water got to this location, how it flows through the study site, where it goes from there, how the area surrounding the water influences the quality of the water particularly during periods of rain, snowmelt, flooding, etc. What questions do they have? Record them on a poster on the classroom wall.

Students at the University of Arizona performing pH, conductivity, and alkalinity measurements.

5. In addition, ask the students to discuss some of the following:
   What land use activities did you observe and list? How do you think these activities would change the water characteristics? Would these activities influence water quality?
   What type of water appearance was recorded most often and what might this indicate about the water quality?
   Was there evidence of human uses of the water? Evidence of wildlife and other animals using the water?

Further Investigations

1. As students visit the site monthly to collect data for the hydrology protocol, remind them of their observations during this activity and ask them to note changes in their GLOBE Science Notebooks.
2. The quantity and the quality of water is a global issue. Take your composite information about your Hydrology Site and prepare a written description of the features and characteristics, including such materials as graphs, of your hydrology data. Contact another school that has reported data and make arrangements to have them graph their hydrology data. Exchange and compare the graphs of the data from both schools. Each should then prepare a written description of the other's Hydrology Study Site based on the comparisons. Then exchange the written descriptions and discuss how the extrapolated descriptions compare with the original descriptions. Explore the things which can and cannot be concluded from the data.

Student Assessment

Have students create a visual display of what they know about their body of water, including surrounding land uses and their impacts on the quality of the water (both positive and negative) in ways that affect fish and animals, including humans, that depend on the water. Share this with others at school and in the community.

Acknowledgment

Adapted from The Aspen Global Change Institute's Ground Truth Studies Teacher Handbook, *River Walk*, and Project WET's *Stream Sense*.

Model Your Watershed

Purpose

To introduce students to their watershed and how it works

Overview

Beginning students construct a three-dimensional model of a watershed and experiment with water flow. Intermediate and advanced students use topographic maps and Landsat images to construct a three-dimensional model of their watershed and test hypotheses about water flow.

Time

For beginning levels: one class period

For intermediate and advanced levels: two to three class periods

Level

All

Key Concepts

A watershed guides all precipitation and run off to a common watercourse or body of water.

The Hydrology Study Site is part of a watershed.

The nature of a watershed is determined by the physical features of the land.

Skills

Modeling a watershed

Predicting water flow

Interpreting maps and images to create a physical model of the watershed

Materials and Tools

For beginning levels:

Plywood sheet approximately 1 m x 1 m

Rocks of various sizes

Plastic sheet

plant sprayer

For intermediate and advanced levels:

Topographic map of your Hydrology Study Site and surrounding area

Landsat image of your GLOBE Study Site (provided by GLOBE)

Plywood sheet approximately 1 m x 1 m

Plaster of Paris, clay or similar material

Waterproofing material or a household plastic wrap

Preparation

Gather the materials

Obtain topographical maps (refer to *How to Obtain Maps and Remote Sensed Images* in the *Toolkit*)

Prerequisites

For intermediate and advanced levels: basic understanding of maps and familiarity with topographic maps and Landsat images

For background information on contour maps, refer to Contour Line Basics in the *Appendix* to this investigation.

Background

The watershed guides all precipitation and runoff (water, sediment, and dissolved materials) to a common watercourse or body of water (catchment). A divide (or watershed) is the ridge between drainage areas. You may have heard of the Continental Divide, the ridge that divides the U.S. and causes all river systems east of it to flow to the Atlantic Ocean and all those west of it to drain to the Pacific Ocean. These large watersheds are made up of smaller ones. In this activity, students will locate their local watershed and create a model of it that will be useful as they study their water system.

Human activities, such as building dams to impound water, diverting water over divides from one watershed to another (transbasin diversion), or changing the topography of the land to build roads and other structures, can alter watersheds. Learning about and modeling a watershed is a way to help people grasp the realities of the water system on which they depend – where the water comes from, where it goes, and what kinds of choices people can make to use and conserve it responsibly.

What To Do and How To Do It

For beginning levels:

1. On the plywood board, place a variety of rocks of different shapes and sizes. Place a plastic sheet over the rocks, push down on the plastic around the rocks to give it shape and to ensure that there are high and low spots.
2. Ask your students what they think will happen when they pour water onto various places of this model.
3. Then, have your students use a plant sprayer to spray water over the surface of the model. Keep on spraying until the water flows. Observe how the water flows and where it collects.
4. Discuss with your students what they observed, paying special attention to how the shape of the model effects the flow of the water.
5. Ask your students what would happen if they move the rocks to different places. Ask them how they might arrange the rocks to have a more rapid, or slower flow of water or to have more or less water collect in a specific location.
6. Have your students rearrange the rocks to test their ideas. Repeat this variation several times.

For intermediate and advanced levels:

1. Ask students:
   What is a watershed?
   Why are watersheds important?
2. Provide students with topographic maps and Landsat images of your area. Help the students to get oriented to what is shown in the topographic map and in the Landsat image and how to correlate the two. Assist the students in using the satellite-derived imagery as a similarly-useful resource. Ask the students to identify their watershed with a name, and find its boundaries. Contour lines and elevation changes on the topographic map are helpful in establishing watersheds. By marking hilltops and ridges, students can create a useful outline of their watershed.
   To begin, students should select an easily identifiable point, such as the mouth of a stream. Working backwards from that point, they should mark other obvious points like peaks and ridges that separate adjacent streams. Ask, "Which way would the water flow from this point?" Have students draw arrows to show drainage patterns. The picture of the watershed will become clearer as more points are identified.
3. Provide students with the materials to build a model of their watershed using one of a number of different media. Plaster of Paris, clay, and/or other materials of your choice will work well. Ask the students to work in small groups to create their model. They should cover the model with household plastic wrap.
4. Once completed, ask the students to spray water on the model and trace the path a drop of water takes across the watershed and into the watercourse.
5. Discuss the relationship between the physical features of the watershed and the location of human activities. Focus especially on the patterns of the flow of water in your watershed.

Further Investigations

1. What larger watershed is your watershed a part of? And which watershed is that larger one a part of? Keep asking yourself this question for larger and larger watersheds. What is the largest watershed of all?
2. Compare recent satellite-derived images with those from earlier time periods. What changes have taken place in the watershed?

Student Assessment

1. Ask students to write an essay about the importance of watersheds.
2. Ask the students to describe how each of the Hydrology protocols is relevant to understanding watersheds and their significance.
3. Have students locate several natural physical features and several human-made features on the topographic map, and satellite images. Locate their corresponding positions on the watershed model.
4. Ask students to describe ways in which the physical features of the watershed could influence future human activities. Let them predict ways physical features of the watershed could influence future human activities.
5. Ask students to describe ways in which human activities change the shape of the watershed, and, consequently, the path along which water will flow.

Acknowledgment

Adapted from *Make A Watershed Model* (Aspen Global Change Institute's Ground Truth Studies Teacher Handbook), with additional information from *Understanding Watersheds* from Tennessee Valley Authority.

Water Detectives

Purpose

To help students understand that there are many substances in the water which they can find using their senses and that there are other substances which they can only identify using tools

Overview

Students will try to identify substances in the water using their five senses. They will then use GLOBE instruments to detect substances in the water.

Time

One class period

Level

Beginning

Key Concepts

Your 5 senses tell you about the world.
Your senses detect different things.
You use tools to help enhance your senses.

Skills

Exploring answers to questions
Developing answers to questions (hypotheses)
Conducting an experiment
Making observations
Recording data
Counting (or adding)

Materials and Tools

For each team of 4 or 5 students:

5 clear plastic cups or jars
5 plastic spoons
Marker to number cups
Items to detect in the water which represent all of the senses, such as:
- Sight - drop of yellow food coloring, lemon juice, carbonated water
- Touch - baking soda
- Smell - lemon juice, vinegar
- Taste* - salt, sugar, distilled water, tap water
- Hearing - carbonated water

Work Sheet

* Use of taste is at the discretion of the teacher.

Preparation

Prepare the water samples for the experiment and duplicate the Water Detectives Work Sheet.

Prerequisites

None

Background

With an average runoff of 30 cm/yr, the hydrologic cycle constantly erodes the continents. A fraction of the eroded material is transported by rivers to oceans, both as suspended solids (e.g. sand, clays, and silts) and dissolved substances (e.g. salts). These can be considered as natural pollutants and can vary from dissolved limestone (calcium carbonate) to dissolved minerals that contain heavy metals such as lead, cadmium, and zinc. Other substances are introduced into the hydrologic system through human activity. Oil, sewage, and chemical fertilizers and pesticides are examples. It is clear that if materials are being carried in the water, all forms of life using that water are subject to the effects of these substances.

Scientists have developed tests to see if various substances, whether harmful or beneficial, naturally occurring or not, are found in water. These tests involve the use of tools to measure substances or properties that humans can not sense directly.

Preparation:

- Provide a work station with cups of water with small amounts of each 'mystery food' substance mixed in for each group (saltwater, carbonated water, etc.). Also provide tap water among the testing cups.
- Lay out spoons for dipping water to feel and to taste.
- Number the cups with the marker.
- Copy the Work Sheet for each student.

What to Do and How to Do It:

Discuss with students how they use their senses to detect things in their environment. Discuss the advantages and limitations of each of the senses. Questions students may want to think about:

1. How do we use our eyes to detect danger? When does our sense of sight not work very well? *(when something is out of vision range, in the dark, invisible...)*
2. How do we use our ears to detect danger? When do our ears not work very well? *(things that make no sound, when we do not listen or pay attention...)*
3. How do we use our sense of smell to detect danger? When does it not work very well? *(some things are odorless, when we have a cold...)*
4. How do we use our sense of touch to detect danger? When does it not work very well? (*when an object is far away, when touching might be dangerous...)*
5. How do we use our sense of taste to detect danger? When does it not work very well? *(when something might be poisonous or unclean...)*
6. Hold up a cup of water. Ask, which of your senses do you think would be most useful for finding out if the water was tap water for drinking? Consider the advantages and disadvantages of using each of your senses.
7. Do you think that just one of your senses would always work for finding out which of the cups contained tap water? Make a guess (hypothesis) as to which of your senses would most often detect mystery foods in the water. On your Water Detectives Work Sheet circle your guess from the pictures at the top of the paper.

Doing the Experiment

1. Show students the boxes of 'mystery food' which have been put in the water (salt, baking soda, etc.) Say, "These are foods that I have mixed into the water in front of you. We are going to use our senses to detect which of these foods are in the cups."
2. Have students look at the cups of water. Have them make an X on the Work Sheet next to the number of any cup that does not look like tap water. Put a W next to any cup that does look like tap water.
3. Have students listen to the cups of water. Have them make an X on the Work Sheet next to the number of any cup that does not sound like tap water. Put a W next to any cup that does sound like a cup of water.
4. Have students smell each cup of water. Have them make an X on the Work Sheet beside the number of any cup that does not smell like tap water. Put a W next to the cups that do smell like tap water.
5. Have students dip a few drops of water from each cup with the spoon to feel the water. Have them put an X on the Work

Sheet next to any cup that does not feel like tap water. Put a W next to any cup that does feel like tap water.

6. Have students dip a spoon in each cup of water to taste it. Tell them to use a clean spoon each time. Have them put an X on the Work Sheet next to the cups that taste different than tap water. Put a W next to any cup that does taste like tap water.
7. Have students count the number of X's under each sense. Which sense had the most X's? This is the sense that was best for detecting what was in the water.
8. Have students review which senses they thought were best for exploring water. Taste? Remind students that it was OK to taste the water today, but ask, "Would you want to taste water if you didn't know anything about what was in it?
9. Ask students what other ways might be used to find out what was in water. Introduce the idea of how we use tools and ask for examples of how we use tools to help our senses. For example, they may think of smoke detectors, microscopes, hearing aids, etc.
10. Introduce students to pH paper as a tool for sensing water. Have students use pH paper to test their cups of water. What can the pH paper detect?

Note: A follow-up activity for pH is the pH Game. Students can explore different pH values of different substances found in their environment.

Adaptation for Older Students:

1. Have students use more advanced tests to determine differences in the water (alkalinity, conductivity, salinity or specific gravity).
2. Challenge students to devise their own tests for detecting differences in the water. (Example: shaking the water, adding other chemicals which might react with things in the water.)

Student Assessment

Ask students to:

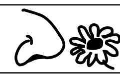
- list several substances found in water
- explain why instruments are sometimes needed to detect substances
- guess (hypothesize) how various substances might affect things living in the water
- explain how each sense is good for examining different kinds of materials
- use the Work Sheet to record their (data) information and see how the work sheet can help them explain the results.

Further Investigations

Have students investigate whether different plants and animals like different types of water.

Water Detectives Work Sheet

*Name:*____________________________________

Cup	See	Hear	Smell	Feel	Taste	pH Test
						
1 one						
2 two						
3 three						
4 four						
5 five						
TOTAL						

Directions for Filling Out the Form

Under the column for each sense and in the row for each numbered cup, put an "X" in each box that represents a liquid that you think is <u>NOT</u> water. Put a "W" in the box that represents the liquid that you think <u>IS</u> water.

Be sure that you use only the sense that is listed in each column when making your decision. When you are done testing each sense for each cup look at the rows to see which one has the most W's. That should be the cup with the water.

The pH Game

Purpose

To teach students about the acidity levels of liquids and other substances around their school so that they understand what pH levels tell us about the environment

Overview

The pH game will engage students in the measurement of the pH of water samples, soil samples, plants and other natural materials from different places. Students will create mixtures of materials in order to collect different pH measurements.

Time

One class period for preparation

One class period for the game

Level

All

Key Concepts

pH measurements

Skills

Taking measurements
Conducting analysis
Interpreting findings
Understanding interrelations in nature

Materials and Tools

For each team (about 4 students):
- 20 pH strips
- 3 or 5 small cups
- Paper and pencil
- Labels with which to attach results to the results board

For the whole classroom:
- Results board for all teams (one line of pH levels from 2 to 9 for each team)
- Flip chart with rules
- Additional pH strips

Preparation

The teacher should prepare various acidic and alkaline mixtures/solutions of natural and processed materials. These solution should be labeled with the ingredients and a letter, but not their acidic or alkaline characteristic. Examples of acidic solutions include fermented grass, dilute and concentrated lemon juice, black coffee, vinegar, orange juice, and soft drinks. Alkaline solutions include salt water, shampoo, baking soda, chlorine bleach, household ammonia, and oven cleaner. Soil solutions produced by mixing water and local soil samples should be used as well as local water samples. The teacher can also produce solutions from materials found around the local school area, such as oil drippings from a vehicle, liquid in a discarded bottle, etc.

Prerequisites

None

Background

The level of acidity (pH) significantly influences the vegetation and wildlife in an environment. The pH can be influenced by different factors. The main influences are the alkaline contributions from rocks and soils, the amount of water in the landscape and also human activities (traffic, buildings, paved surfaces, etc.). Acid rain may also have an important impact on water pH. It is important to understand these relationships. This simple activity will help your students to understand the interdependence of nature and human activities.

Note: Remind students of the difference between hypothesis and results. Encourage them to develop their hypothesis and find a way to test it with results (prepare some literature for them, invite an expert to the class, examine past measurements, etc.).

The Rules

1. Explain to students the objective of the game is that each team identifies solutions which have a pH range of 2-9.

   The students should draw a horizontal pH scale line from 0 to 14, marking pH 7 as the neutral point. Each unit should be spaced at least 1 cm apart. They should then draw a box underneath each pH unit from 2 to 9.

   Each team finds substances that have a pH corresponding to a box in the pH scale.
2. The teacher draws the following matrix on the board. See Matrix HYD-L-1.
3. One point is awarded for each box filled, even if the team finds two samples with the same pH.
4. Students should record all the information about the solution from the labels and the pH they measured.
5. When students are ready to submit a sample for the game results board, they show the teacher their notes and sample. Together they measure the pH with a new pH strip. If the pH agrees with the students' previous measurement, the sample is approved and the points are added to the team's score. The table below is an example of results for different teams. See Matrix HYD-L-2.
6. The teacher gives a new pH strip for each sample added to the results board.

Matrix HYD-L-1

	pH Value								
Teams	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**TOTAL**
Team 1									
Team 2									
Team 3									

Matrix HYD-L-2

	pH Value								
Teams	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**TOTAL**
Team 1	1		1			1	1		4
Team 2		1		1				1	3
Team 3	1				1		1		3

Modifications for different ages

Beginning

For a basic understanding, use salt and sugar and explain to students that salty does not necessarily mean acid and that sweet does not necessarily mean alkaline. Cola soft drinks are good examples of a sweet and very acid liquid.

Intermediate

Make the game more competitive. For instance, the team that finds or creates the first sample of a particular pH value receives 5 points; subsequently, samples for that pH level receive only 1 point.

Make the game more difficult by limiting the sample sources to only natural materials.

Limit the number of pH strips given to each group and set up a rule for buying a new one with game points.

Advanced

Ask the students which solutions should be added together to produce a neutral solution. Have them test their hypothesis by adding some of the labeled solutions together and recording the pH. Have students quantify the neutralization capacity of different solutions. Relate this to buffering capacity (alkalinity) of hydrology sites.

Provide students with samples of solutions from other parts of your country (or of the world) and ask them to characterize how they influence pH differently.

Conduct a similar analysis of samples from different geological layers or different areas of the community or study site.

Note: For older students we recommend inviting an expert to answer their questions.

Further Investigations

Examine the Hydrology Study Site for materials in soil, rocks, and vegetation that influence the pH of the water.

Try to identify and quantify influences that are not always present at the study site, such as precipitation or some event upstream of your sampling site.

Student Assessment

After the game sit with students around the results board and identify what samples they have found, where the samples were found, and the pH of the samples. Encourage students to present their own ideas about why different samples have different pH values. Emphasize differences among water samples from soils, rocks, artificial surfaces, lakes, rivers, etc. Mention the acid neutralization capacities (alkalinity) of some rocks and the acidic influences of different materials. Ask them why it was difficult to find samples for some pH levels and easy to find others.

Acknowledgments

The pH game was created and tested by the leaders team of TEREZA, the Association for Environmental Education, Czech Republic.

Practicing the Protocols

Purpose

To have students:

1. learn how to use each of the hydrology instruments correctly
2. explore the ranges of measurements possible with each instrument
3. use each instrument as directed in the protocol
4. understand the importance of quality control.

Overview

Groups of students will rotate among measurement stations for each of the protocols that will be performed by the class. They will practice using the instrument or kit and protocol for that particular measurement, exploring sources of variation and error. The activity concludes with students testing water samples brought from a variety of places (home, yard, puddles, brooks, etc.).

If you have enough instruments and kits, you may want to focus on a subset of the measurements during a given class period in order to simplify the discussion.

Time

Three to four class periods

Level

Varies with the protocol

Key Concepts

Quality assurance
Quality control
Reliability
Accuracy
Protocol
Calibration

Skills

Following directions carefully
Performing measurements

Materials and Tools

Refer to the *Hydrology Protocols* for the instruments, equipment and kits required for each protocol.

One bucket of tap water

Copies of Hydrology Investigation Student Activity Sheets

In addition you will need the following materials for particular protocols:

Transparency: green food color, spoonful of silt

pH: samples of vinegar water, distilled water, milk, juice, soda pop, etc.

Temperature: ice

Conductivity: distilled water, salt

Salinity: distilled water, salt, ice

Nitrate: lawn fertilizer

Preparation

Ask students to bring in water samples from the home and/or yard.

Set up measurement stations for each of the protocols your students will be performing. For each station you will need:

Equipment and instruments to perform the measurement

One copy of the protocol to be posted at the station

Copies of the Hydrology Investigation Student Activity Sheet.

Draw a bucket of tap water at the beginning of the day and allow it to sit until class. Record the time on a piece of tape attached to the bucket.

Fill a Dissolved Oxygen sample bottle at the same time and preserve the sample as directed in the protocol. Record the time on the sample bottle label.

Prerequisites

None

Background

A quality assurance and quality control (QA/QC) plan is necessary to ensure test results are as accurate and precise as possible. Accuracy refers to how close a measurement is to true value. Precision means the ability to obtain consistent results. Desired accuracy, precision and reliability are ensured by:

- careful calibration, use, and maintenance of testing equipment
- following the specific directions of a protocol exactly as described
- repeating measurements to ensure that they are within acceptable limits
- minimizing contamination of samples, stock chemicals and testing equipment
- keeping track of samples.

Together these steps help make the data you collect valid, valuable and meaningful.

Calibration

Calibration is a procedure used to check the accuracy of testing equipment. To assure that the equipment is functioning properly, a solution of known value is tested. Calibration procedures vary among the measurements and are detailed in each protocol.

Safety

Consult Material Science Data (MSDS) sheets that come with the kits and buffers. Also consult your local school district's safety procedure guidelines.

What To Do and How To Do It

1. Divide the students into small groups, optimally three per group. Checking each others work, students should take turns reading directions, making measurements, and recording the data.
2. Students rotate through each station learning the instruments and protocols.
3. Reconvene the class. For each measurement:

   3.1. Plot all the data points as a way of helping students visualize the concept of precision. When measurements are precise, points are close together. Discuss the range of measurements found and variations among the measurements.

   3.2.Brainstorm with students the issue of why there are discrepancies. This is the time to bring up calibration against standards, reliability, accuracy, and adherence to protocols. Connect explanations with reasons for specific steps in the protocols. Stress the importance of making accurate measurements so they can compare different samples.
4. Compare the results they obtained on samples from various places. Help them make sense of their results by placing data on a map of the water sources and considering the history of each sample in terms of well water, city water, pool, pond, puddle or brook. This is also a good time to stress the importance of accurate measurements when you make comparisons. Is the difference real or measurement error? This is also the time to discuss why we didn't test these samples for DO and temperature and how we might test for them.

Adaptations

Beginning students

Focus on one measurement at a time, following the outline given above.

Advanced students

Have students create their own data plots and interpret them.

Further Investigations

Repeat the above explorations but vary one parameter-such as temperature by cooling one third of each water sample, and heating one third of the water samples, with the remaining one third at room temperature. Then compare the effect of water temperature on the other measurements.

Hydrology Investigation
Student Activity Sheet

Transparency Station

Background

Transparency is the measurement of water clarity. How clear the water is at your site will depend on the amount of soil particles suspended in the water and on the amount of algae or other growth at your site. Transparency may change seasonally with changes in growth rates, in response to precipitation runoff, or for other reasons. The clarity of your water determines how much light can penetrate. Since plants require light, transparency becomes an important measurement in determining productivity of your water site.

In the field you would measure transparency in one of two ways; with a Secchi disk in deep, still waters or with a turbidity tube if your site has shallow or running water. For the lab practice station, we will use the turbidity tube.

What To Do and How to Do It

1. Ask each student to fill the turbidity tube with tap water until the image disappears. Record the depth of the water in the tube in cm.
2. Compare data from several students. Ask students to formulate hypotheses on variations in their data.
3. Try the tube again testing variables such as: amount of light in the room, tube in sunlight and shadow, with and without sunglasses, turning the tube to try and detect the image at the bottom, letting the water stand in the tube for 15-20 seconds.
4. Once students have established the depth using tap water, pour the water into a bucket and mix a few grams of silt into the water.
5. Ask students to fill the turbidity tube with the silty water until the image disappears. Record the depth of the water in the tube in cm. Compare the readings from several students.
6. Put a few drops of green food coloring in tap water.
7. Have each student fill the turbidity tube with colored water until the image disappears.

Student	Sample Tested	cm

Hydrology Investigation
Student Activity Sheet

Temperature Station

Background

Water temperature is the temperature of a body of water such as a stream, river, pond, lake, well, or drainage ditch as it appears in nature. Water bodies can vary greatly in temperature, according to latitude, altitude, time of day, season, depth of water, and many other variables. Water temperature is important because it plays a key role in chemical, biological and physical interactions within a body of water. For example, high temperatures may be an indicator of increased plant production. The temperature of the water determines what aquatic plants and animals may be present since all species have their natural limits of tolerance to upper and lower temperatures. Water temperature can therefore help us to understand what may be happening within the water body without directly measuring hundreds of different things within the body of water.

What To Do and How To Do It

1. Following the steps in the *Water Temperature Protocol*, each member of the group should take a turn measuring the temperature of the same sample with the same thermometer. Make sure everyone in the group can read the thermometer. Compare your readings. Are they within 0.5° C of each other? Why? Why not? If not, repeat this exercise with another water sample until you are obtaining readings within 0.5° C of each other.
2. With each member of the team using a different thermometer and following the steps of the water temperature protocol, measure the temperature of a single water sample and compare your readings. Do you get readings within 0.5° C of each other? Why? Why not? If not, your thermometers may need calibration.
3. Following the steps in the water temperature protocol, measure the temperatures of water from the hot and cold water taps, ice water, and the water that has been standing in the bucket. List the things you checked and record the temperatures you obtained for them.
4. Discuss the range of measurements possible with each of the thermometers. Can you take temperatures below the freezing mark? Why? Why not? Can you take the temperature of boiling water with the thermometer provided? Why? Why not?

Student	Sample Tested	Temperature

Hydrology Investigation

Student Activity Sheet

Dissolved Oxygen Station

Background

All living things depend on oxygen to survive. In a water environment molecules of oxygen gas dissolve in the water. This is called dissolved oxygen (DO). In air, 20 out of every 100 molecules are oxygen. In water, only 1-5 molecules out of every million molecules are oxygen. This is why dissolved oxygen is measured in parts per million (ppm). Different species of aquatic organisms require different amounts of oxygen, but generally aquatic organisms require at least 6 ppm for normal growth and development.

Water temperature and altitude influence how much oxygen water can hold; i.e., the "equilibrium" value. In general, warmer water cannot hold as much oxygen as colder water. Similarly, at higher altitudes water cannot hold as much oxygen as waters at lower altitudes. Look for these patterns in the Temperature and Altitude Tables in the DO protocol. This is why we use a distilled water standard in the protocol and correct for temperature and altitude.

The actual amount of DO in a water may be higher or lower than the equilibrium value. Bacteria in the water consume oxygen as they digest decaying plant or animal materials. This can lower the DO levels of the water. In contrast, algae in lakes produce oxygen during photosynthesis which can sometimes result in higher DO levels in summer.

What To Do and How To Do It

1. Following the steps in the *Dissolved Oxygen Protocol*, each member of the group takes a turn measuring the DO of the same sample. Compare your readings. Are they within 0.2 mg/L of each other? Why? Why not? If not, repeat this exercise with another water sample until you obtain readings within 0.2 mg/L of each other.
2. If your water faucets have aerators on them, test a water sample freshly drawn from the faucet, one that was drawn at the beginning of the day and allowed to sit undisturbed in a bucket, and the preserved sample drawn at the same time. Record the time at which you tested the water in the bucket. How long has it been since the water was drawn? Compare the readings. Are they different? Why? Why not? What might account for the differences?

Student	Sample tested	Time	DO

Hydrology Investigation
Student Activity Sheet

pH Station

Background

pH is an indicator of the acid content of water. The pH scale ranges from 1 (acid) to 14 (alkaline or basic) with 7 as neutral. The scale is logarithmic so a change of one pH unit means a tenfold change in acid or alkaline concentration. For instance, a change from 7 to 6 represents a solution 10 times more acidic; a change from 7 to 5 is 100 times more acidic, and so on. The lower the pH the more acidic the water. The pH of a water body has a strong influence on what can live in it. Immature forms of salamanders, frogs, and other aquatic life are particularly sensitive to low pH.

What To Do and How To Do It

1. Following the steps for pH paper in the *pH Protocol*, each member of the group takes a turn measuring the pH of the same sample. Compare your readings. Are they within 1.0 pH units of each other? Why? Why not? If not, repeat this exercise with another water sample until you are obtaining readings within 1.0 pH units of each other.
2. Without calibrating the pH pen, but following the steps for the pen given in the *pH Protocol*, take turns measuring the pH of a different water sample. Record these numbers.
3. Calibrate the pH pen and repeat the measurements again following the protocol carefully to avoid contaminating samples. Alternatively, students could use one calibrated pen and one that has not been calibrated if there is enough equipment. Record your readings.
4. Compare the data obtained using different methods. Discuss possible reasons for the differences.
5. Take the pH of familiar liquids such as distilled water, vinegar, tap water, milk, juice, soda pop, etc. using pH paper, uncalibrated pH pens, and calibrated pH pens.
6. List the samples you checked and record the pH obtained by the different methods. Which methods gave the most accurate results? The most reliable?
7. Create a pH scale and plot the average values obtained for each sample.

Sample tested	pH paper	uncalibrated pH pen	calibrated pH pen

Hydrology Investigation
Student Activity Sheet

Electrical Conductivity Station

Background

Electrical conductivity is a measure of the ability of a water sample to carry an electrical current. Pure water is a poor conductor of electricity. It is the impurities in water, such as dissolved salts, that enable water to conduct electricity. Therefore, conductivity is often used to estimate the amount of dissolved solids in the water since it is much easier than evaporating all the water molecules from a sample and weighing the solids that remain.

Conductance is measured in a unit called the microSiemen/cm. Sensitive plants can be damaged if they are watered with water that has electrical conductivity levels above about 2200-2600 microSiemens. For household use, we prefer water with conductivity below 1100 microSiemens. Manufacturing, especially of electronics, requires pure water.

What To Do and How To Do It

1. Following the steps in the *Electrical Conductivity Protocol*, each member of the group takes a turn measuring the conductivity of the same tap water sample. Compare your readings. Are they within 40 µSiemens/cm of each other? Why? Why not? If not, repeat this exercise with another water sample until you are obtaining readings within 40 µSiemens/cm of each other.
2. Without calibrating the electrical conductivity pen, but following the steps of the protocol, take turns measuring the conductivity of distilled water, tap water, and distilled water to which you have added a pinch of salt. Record those numbers.
3. Calibrate the pen and repeat the measurements following the protocol carefully to avoid contaminating samples. Record your readings below.
4. Compare the data obtained using the uncalibrated pen and the calibrated pen. Is there a difference? Discuss possible reasons for the differences. Is one pen always higher or lower than the other? By the same amount?
5. Measure the conductivity of familiar liquids such as vinegar, drinking water, milk, juice, soda pop, etc.

   List the samples you checked and record the results.
6. What is the range of conductivity readings? Create a conductivity scale and plot the value obtained for each sample.

Sample tested	uncalibrated conductivity pen	calibrated conductivity pen
distilled water		
tap water		
salty water		

Hydrology Investigation
Student Activity Sheet

Salinity Station - for Salt or Brackish Water

Background

Salinity is the measurement of dissolved salts in salty or brackish water. It is measured in parts per thousand (ppt). Salinity may vary with precipitation, snow melt, or proximity to a freshwater source such as a river mouth.

The hydrometer is an instrument which measures the specific gravity or density of a fluid. Its design is based on the principle, recognized by the Greek mathematician Archimedes, that states that the weight loss of a body in a liquid equals the weight of the liquid displaced. The denser your liquid, therefore, the less the weighted bulb must sink to displace its own weight.

Why do you need to take a temperature reading with your hydrometer reading? Water becomes more dense as it approaches freezing - then less dense as it becomes ice. Since we want to measure the effect of dissolved salts on density, we must control the temperature variable.

What To Do and How To Do It

1. Fill a 500 mL cylinder with fresh water to the 500 mL line.
2. Gently place the hydrometer into the cylinder (do not drop).
3. Read the scale on the hydrometer at the bottom of the meniscus. Record.
4. Remove the hydrometer and add 7.5 grams of salt to the cylinder. Stir.
5. Use a thermometer to measure the temperature in the cylinder 10 cm below the surface. Record.
6. Use the hydrometer to measure the density of the fluid in the cylinder. Record.
7. Look up the salinity of your fluid from the table using the temperature and hydrometer readings. Record.
8. Add 10 grams of salt to your mixture.
9. Measure the temperature and salinity of the fluid. Record.
10. Add a few pieces of ice to the cylinder.
11. Measure the temperature and salinity of the fluid. Record.

Examine the data which you have recorded. The salinity of fresh water should be 0. As you add salt to the water, the salinity should increase. Changing the temperature will affect the density of the water, but should not affect the salinity after the conversion is done.

Discuss any variations between students. Repeat the measurements if variations exceed 2 ppt.

Work Sheet for Salinity Station

Sample	Temperature	Hydrometer	Salinity	Student/s
Fresh water				
7.5 grams salt				
17.5 grams salt				

Hydrology Investigation

Student Activity Sheet

Alkalinity Station

Background

Alkalinity is a measure of the ability of a body of water to resist changes in pH when acids are added. Acid additions generally come from rain or snow, although soil sources may also be important in some areas. Alkalinity is generated when water dissolves rocks such as calcite and limestone. The alkalinity of natural waters protects fish and other aquatic organisms from sudden changes in pH.

What To Do and How To Do It

1. Following the steps in the *Alkalinity Protocol*, each member of the group takes a turn measuring the alkalinity of the same sample of tap water. Compare your results. Are they within one drop or titrator unit of each other? Why? Why not? If not, repeat this exercise with another tap water sample until you are obtaining results within one drop or titrator unit.
2. Test the water samples you have brought to class from other sources.
   List the source of the water sample and the results obtained. Compare the alkalinity of these samples. What is the range of results? Why are there variations?

Student	Sample tested	Reading

Hydrology Investigation
Student Activity Sheet

Nitrate Station

Background

Nitrogen is one of the three major nutrients needed by plants. Most plants cannot use nitrogen in its molecular form (N_2). In aquatic ecosystems blue-green algae are able to convert N_2 into ammonia (NH_3) and nitrate (NO_3^-) which can then be used by plants. Animals eat these plants to obtain nitrogen that they need to form proteins. When the plants and animals die, protein molecules are broken down by bacteria into ammonia. Other bacteria then oxidize the ammonia into nitrites (NO_2^-) and nitrates (NO_3^-). Under suboxic conditions nitrates can then be transformed by other bacteria into ammonia (NH3), beginning the nitrogen cycle again.

Typically nitrogen levels in natural waters are low (below 1 ppm nitrate nitrogen). Nitrogen released by decomposing animal excretions, dead plants, and animals is rapidly consumed by plants. In water bodies with high nitrogen levels eutrophication can occur. Nitrogen levels can become elevated from natural or human-related activities. Ducks and geese contribute heavily to nitrogen in the water where they are found. Man-made sources of nitrogen include sewage dumped into rivers, fertilizer washed into streams or leached into groundwater, and runoff from feedlots and barnyards.

Nitrate levels are measured in milligrams per liter nitrate nitrogen.

What To Do and How To Do It

1. Following the steps in the *Nitrate Protocol*, measure the nitrate level of the water sample. Compare the readings of several students. Are they within 0.2 mg/L of each other? If not, discuss possible reasons for error. Repeat the readings until you obtain readings within 0.2 mg/L.
2. Repeat the protocol with the same water, but shake the sample for half of the time given in the protocol.
3. Repeat the protocol with the same water, but leave the sample to set for five minutes beyond the time given in the protocol.
4. Measure the nitrate level in a number of different water samples: runoff from a golf course, other pond water, a stock tank, river, etc. List the sources of water and record your results.
5. Add a few grains of fertilizer to your sample. Test again. What is the difference?
6. Discuss possible sources of nitrogen in your water samples.

Sample Tested	Reading	Student

Water, Water Everywhere! How Does It Compare?

Purpose

To see how water characteristics can vary with location and to encourage students to see how other sites compare to theirs. To illustrate to students how scientists are beginning to explore their data and to encourage students to begin their own data analyses.

Overview

Students will be asked to examine initial student data which scientists have identified from the GLOBE data set. After reading the scientist's comments about the data, students will then be asked to find additional data from GLOBE schools to explore and analyze.

Time

One class period for the initial activity and ongoing for follow-up

Level

Intermediate and Advanced

Key Concepts

Water characteristics vary (within some limits).

Data are used to pose questions.

Data are used to answer questions.

Skills

Graphing data

Making comparisons over space and time

Analyzing data for trends and differences

Forming hypotheses

Testing hypotheses

Using the GLOBE database

Materials and Tools

Pencil and graph paper, or computer tools

Computer and the GLOBE Student Server

GLOBE Science Notebooks

Preparation

Collect GLOBE data.

Prerequisites

None

Background

Although it sometimes takes many years to develop a data set to explore or answer questions about a site, GLOBE scientists have already begun to examine the growing set of GLOBE Hydrology data to get early indications of interesting trends and to monitor data quality. To help students begin to examine their own data and data from other schools, the GLOBE hydrologists want to share their preliminary investigations with you. Below you will find the early results from the analysis of pH and temperature data, as well as some interesting questions posed by examining other hydrology data. Since these investigations are ongoing, there will be updates as new data come in. These will be posted on the GLOBE Student Data Server at the Scientist's Corner. You can also find additional information on regional analyses on the WEB pages.

As more and more data become available in the archive, scientists will be continuing their efforts to look for interesting trends and to ask more questions. Students can assist in this effort by monitoring and analyzing the data over time from their own sites as well as from other sites around the globe and sharing their ideas and research with others in the GLOBE network.

What To Do and How To Do It

Section 1 of this activity contains a series of graphs that have been generated from GLOBE data on pH and temperature. These were chosen to illustrate particular questions commonly posed by students or data quality problems commonly observed by scientists. Each set of graphs can be used as a starting point for further investigations or discussion of data analysis.

Begin by showing students the graph of 'typical' pH data and temperature readings. Discuss expected trends in data sets and encourage questions or comments on the data.

Then, with each of the following sets of graphs have students examine the data and pose hypotheses or ask questions about what they are observing. Record their observations. Once your students have examined the graphs and recorded their observations and hypotheses, compare their conclusions with what the scientists think may be happening. These recordings should be done in the students' GLOBE Science Notebooks. Students may then move on to the Further Investigations to analyze their own data or data from other sites.

In Section 2, GLOBE scientists have begun the initial examination of the newer GLOBE protocols: dissolved oxygen, alkalinity, and conductivity. Students can examine our graphs, then try to identify trends and problems with the new data measurements.

The graphs below can also be found on the WEB in the Scientist's Corner. Teachers may use these in print form, make overheads, or have students work at computer stations. In addition, more graphs and information on further research by GLOBE scientists are available on the WEB and can be downloaded for printing or used on the computer.

Note: Copies of the graphs included in the activity are available in larger format in the *Appendix*. These can be used to make overheads for instruction or for duplication and distribution to students for analysis or assessment.

What is an example of a typical GLOBE data set?

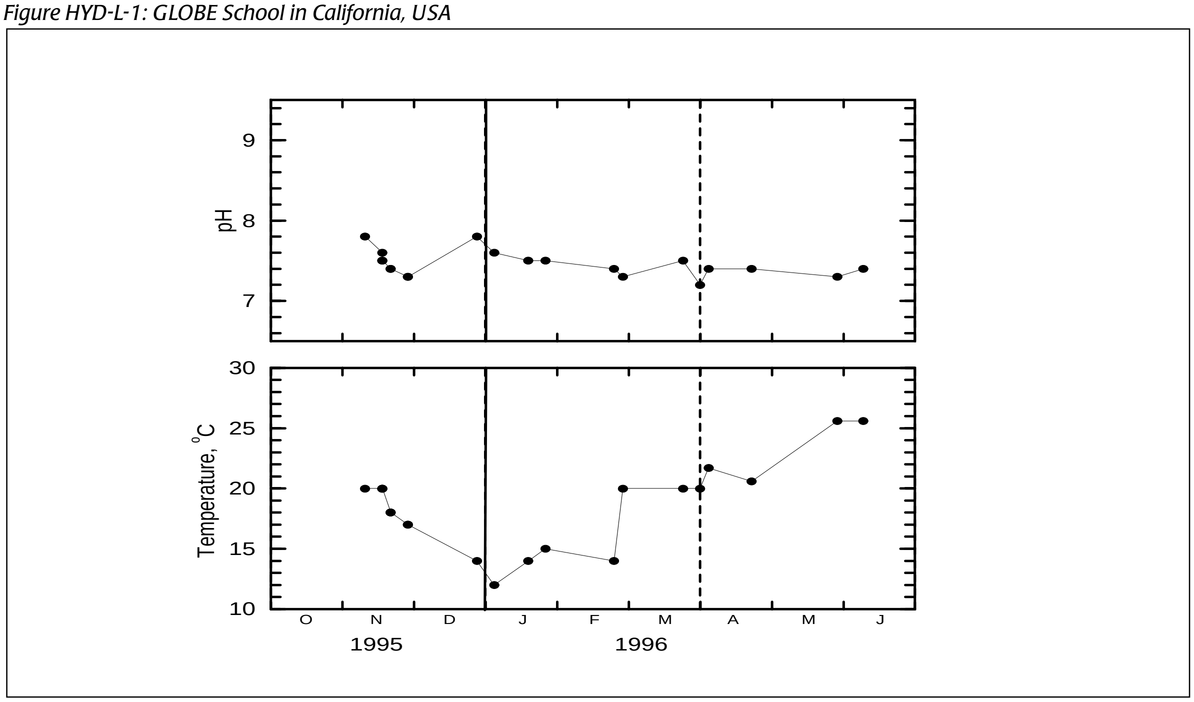
Typical characteristics

- pH data go up and down, but within a reasonable range.
- Temperature jumps around a little, but follows a seasonal trend.

Are there unusual things even in this data set?

Sure there are! Take a second look and think about the graphs in Figure HYD-L-1. Do you see anything surprising? Look at the jump up in pH from November to December! It could be a result of testing methods, but it might also be real! If

Figure HYD-L-1: GLOBE School in California, USA



equipment has been calibrated and multiple testing has shown the same result, these students should be trying to identify other factors which might cause an increase.

Section 1 - pH and Temperature Data

Part 1 - Identifying Outliers

1. Show students the graphs in Figures HYD-L-2 and HYD-L-3. After they have had an opportunity to examine the graphs and record their observations, ask them to identify any unusual data points.
2. Discuss the importance of data quality. Ask students what they should do if some data points are far beyond the range of the rest of the set (are they outliers)?
3. Discuss their observations and recommendations.

Note from the scientists

We have plotted all of the data as time series graphs. Before we can discern trends and compare data from different sites, we go through the data carefully looking for outliers. For example, notice in Figure HYD-L-2 that one temperature reading lies outside the range of the others. This is probably an error, and we will remove this point from our analysis before continuing.

In addition, pH readings that deviate significantly from the average are suspect. For Figure HYD-L-3, note the single pH 4 reading, with the rest of the pH's being in the 6-9.5 range.

Some additional items of interest can be seen looking at these graphs. Figure HYD-L-3 shows what appears to be a pH trend gradually climbing over the course of the record. The pH's seem to be more scattered than would be expected. Why do you suppose this is the case? In Figure HYD-L-2, we see a more typical variation in pH values, with a gradually increasing trend. This might be a problem associated with a buffer solution that was losing its accuracy, or it might actually represent a real pattern in nature!

Further Analysis

Encourage students to look at their own data. Time series graphs may be generated by importing GLOBE data into a spreadsheet, or by using the new GLOBE graphing tools to graph student data.

Figure HYD-L-2: GLOBE School in California, USA

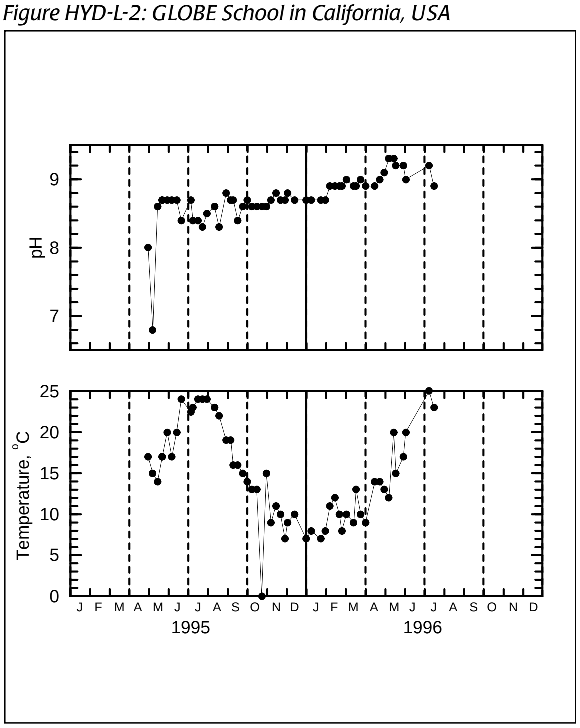
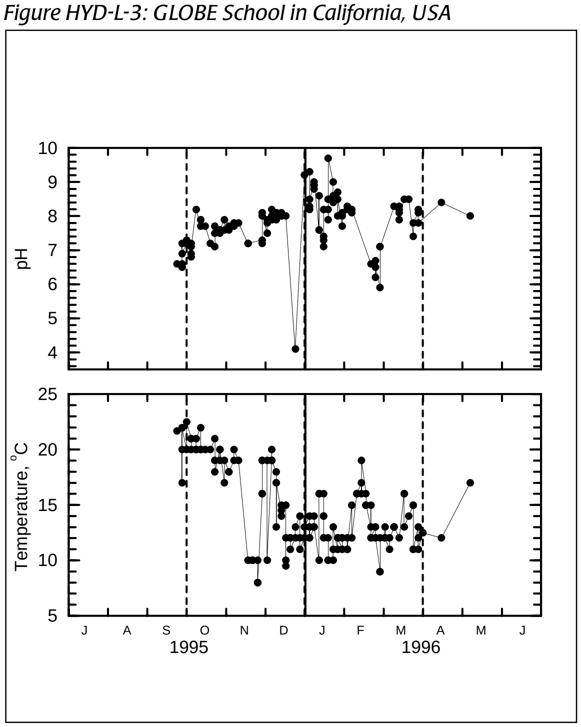


Figure HYD-L-3: GLOBE School in California, USA



The graphing tools can be accessed at the GLOBE visualization location on the GLOBE Student Server. Instructions for accessing the graphing capabilities are available in the Toolkit. Have students try to locate outliers in their own data to minimize the possibility that calibration error or measurement inconsistencies may be influencing data.

You may also use GLOBE visualizations to try to identify daily observations that may be unusual. See Figure HYD-L-6. Students should generate point and contour maps of the weekly observations to try to identify unusual patterns; for example, a light blue point (very low temperature) within an area of orange and red points (warm temperatures). If students find questionable data, they may then locate the data set for that site and try to identify reasons for the anomaly or contact the site using GLOBEMail to ask questions about the data.

Part 2 - Investigating the Range of pH Values

My pH values are jumping around unpredictably.

Figure HYD-L-4: GLOBE School In Florida, USA

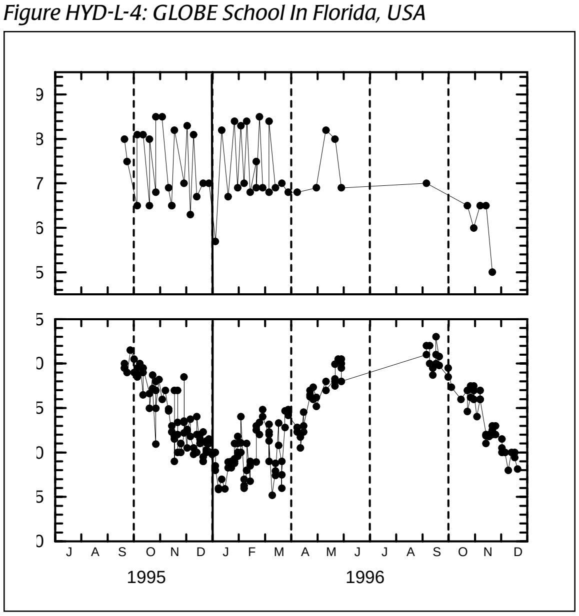
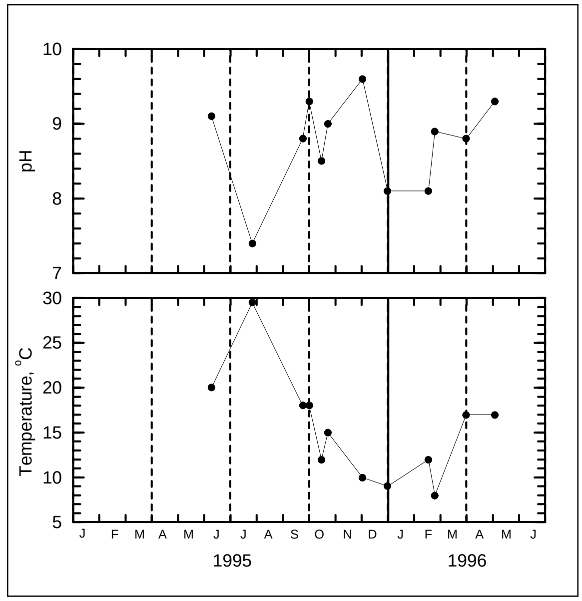


Figure HYD-L-5: GLOBE School in Washington, USA



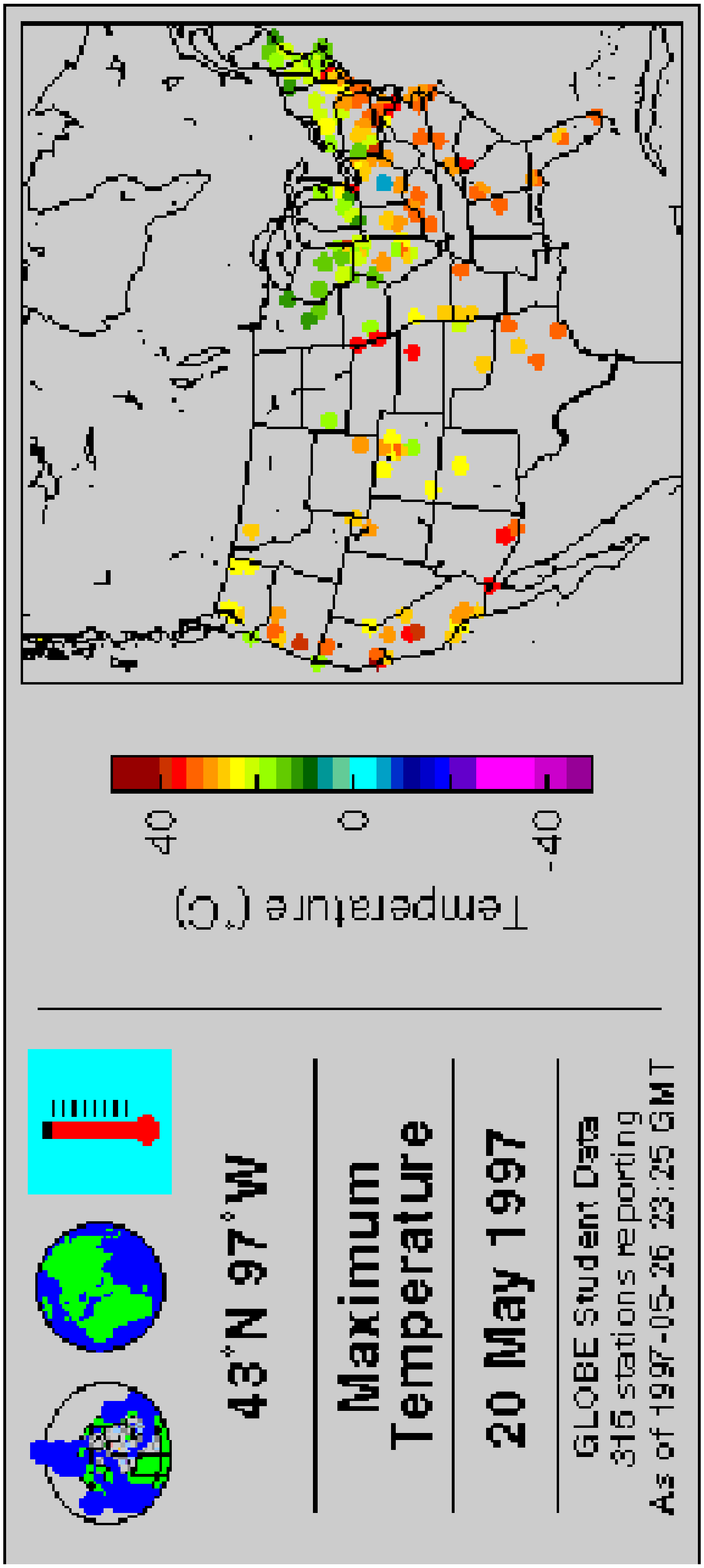
Is this right? Should my pHs be this jumpy?

1. Show students the 2 sets of graphs in Figures HYD-L-4 and HYD-L-5. After they have had an opportunity to examine the graphs and record their observations, ask them to identify any unusual trends.
2. Discuss the range of pH that the students have been finding at their own site. How much variation in pH readings have they found?
3. Have students use the GLOBE graphing tools to graph their own pH data and that of a few other schools. What is the range of their data?
4. Discuss their observations and recommendations.

Note from the scientists

These graphs in Figures HYD-L-4 and HYD-L-5 are good examples of curious pH readings in data sets. Here the pH values seem to be bouncing back and forth over a range of almost 3 pH units. What do you think might be going on in this case? Keep in mind that pH's are usually fairly steady measurements unless there is a major disturbance to a stream or lake such as periodic waste discharge, a very large rainfall, a large algae bloom, or a change in flow rate due to upstream snowmelt. A good example of a periodic change in water flow might also be the discharge from a reservoir upstream. This would significantly affect

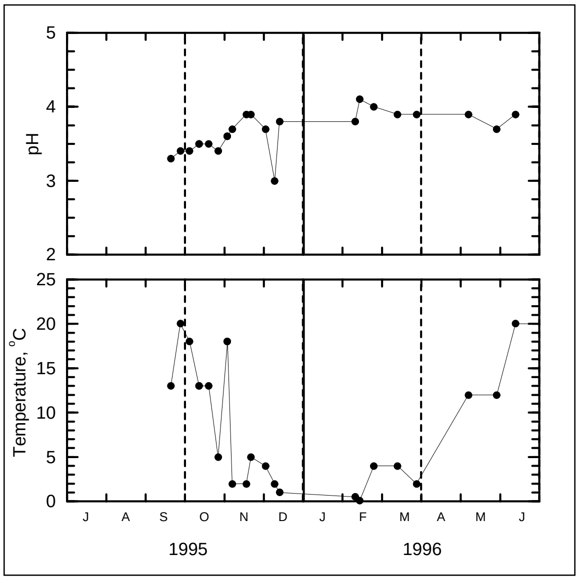
Figure HYD-L-6: Temperature from GLOBE Student Data Server



pH values measured downstream. This set of temperature data shows nice, predictable seasonal trends. Are there major disturbances going on, or do these data merely reflect part of the learning process?

I wonder why we're finding such low pH values?

Figure HYD-L-7: GLOBE School in New Jersey, USA



1. Show students the set of graphs in Figure HYD-L-7. After they have had an opportunity to examine the graphs and record their observations, ask them to identify any unusual trends. Would they expect pH readings to be this low? Have them explain why or why not. They should justify their explanation using the data and background information about pH.
2. Ask students to form a hypothesis on why the pH results are so low for this site.
3. Ask them how they could test their hypotheses.
4. Identify other sites from the GLOBE Student Server in the same area. Retrieve the data for these sites and compare them to this site.

Note from the scientists

This graph in Figure HYD-L-7 is an excellent example of a hydrology site exhibiting low pH readings. The question is how likely is it that the pH of the water is really this low? This graph shows a pH data range of about 3 to about 4.5. Natural waters tend to be in the pH range of 6 to 8.

Possibilities

- This is real! If you think this is the case, then the next step is to ask yourselves and your classmates why the pH is so low. What does this say about the path the water has followed to reach this Hydrology Study Site?
- This is a product of how you did your tests. Unfortunately, although we all try our best to make sure our data are accurate, sometimes there is one step we missed which is causing an error in our data. Other times, the materials we have to work with are not in good shape. In the case of low pH values, it seems most likely that the solutions that the school is using for calibration are no longer good. Certainly testing these standards is a good place to start.

Testing your Standard Solutions

To investigate the possibility that your Standard Solutions are not good, you have a couple of choices:

- Buy a new set of standard solutions and compare them to your old ones.
- Calibrate your pH meter with your solutions, then use it to test the pH of a freshly opened soft drink. These products, due to their production standards, are consistently the same pH and can be used as a comparison to see if your pH meters are measuring correctly.

Below is a set of pH's for several soft drinks at room temperature:

Coca-Cola 2.5
RC-cola 2.5
Mr. Pibb 2.8
Pepsi-Cola 2.5
Sprite 3.2

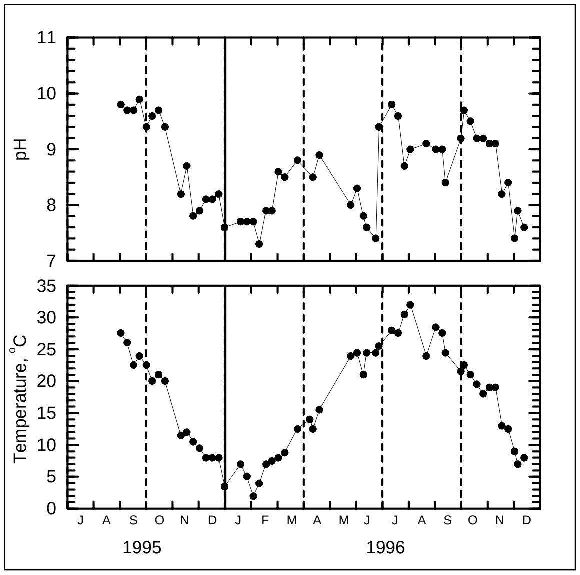
Further Investigations

Have students test their own instruments using the information above.

Part 3 - Identifying pH and Temperature Patterns

This is neat! My pH values and temperatures are going up and down smoothly!

Figure HYD-L-8: GLOBE School in Japan



1. Show students the set of graphs in Figure HYD-L-8. After they have had an opportunity to examine the graphs and record their observations, ask them to identify any unusual trends.
2. Ask students to form a hypothesis on why the temperature graph would show the pattern it does. Does pH normally follow temperature this closely?
3. Graph your own data and data from other sites, especially Japan, using the GLOBE graphing tools, to compare the data with these graphs.

Note from the scientists

Sometimes everything you're doing seems to be right, and you notice what seems to be a really neat trend to your data! As a contributor to the scientific body of knowledge, it is important to look at your data and keep checking to see if you are being accurate. In Figure HYD-L-8 showing data from a GLOBE school in Japan, we see what looks like a consistent and smooth trend in pH. It seems to follow the temperature to a remarkable degree, and even seems to be within a more or less acceptable range.

The data look good! Why the concern?

The data look good because there do not appear to be any major jumps in the measurements, the data are consistently being entered, and the temperature measurements show a smooth and predictable trend. However look at the next couple of observations...

- It is quite unusual for natural processes to change pH by more than 1 or 1.5 units. Also pH values above pH 9.0 are not that common in lakes and streams.
  It would be interesting to see if other schools in the same area show the same trends.
- Although temperature and pH are related to some degree, we would not expect such strong correlation as a result. The pH meters should also be designed to automatically correct for temperature. Was that true in this case?

Part 4 - How will pH Paper and pH Meters Differ?

What was used to take these pH measurements: a pH meter or pH paper?

1. Explain that students in different schools may be using pH paper, pH pens and pH meters to collect pH data.
2. Show students the sets of graphs in Figures HYD-L-9 and HYD-L-10. After they have had an opportunity to examine the graphs and record their observations, ask them to form a hypothesis on what instrumentation was used to take the pH measurements.
3. Ask students how they can justify or support their hypotheses regarding the instrumentation used in collecting the pH data.

Figure HYD-L-9: GLOBE School in the Midwest of the United States

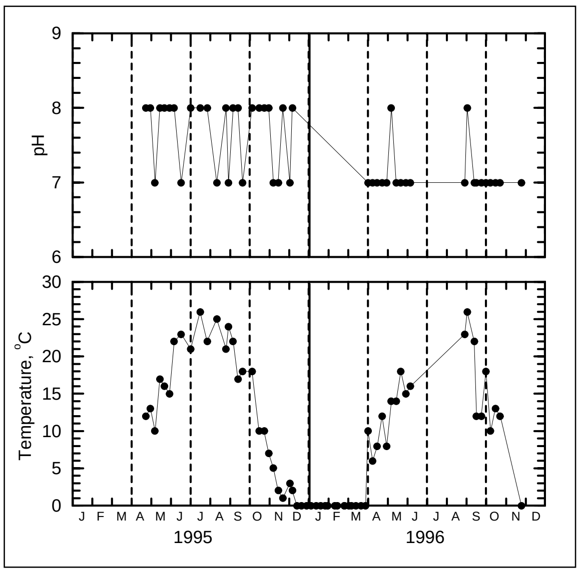
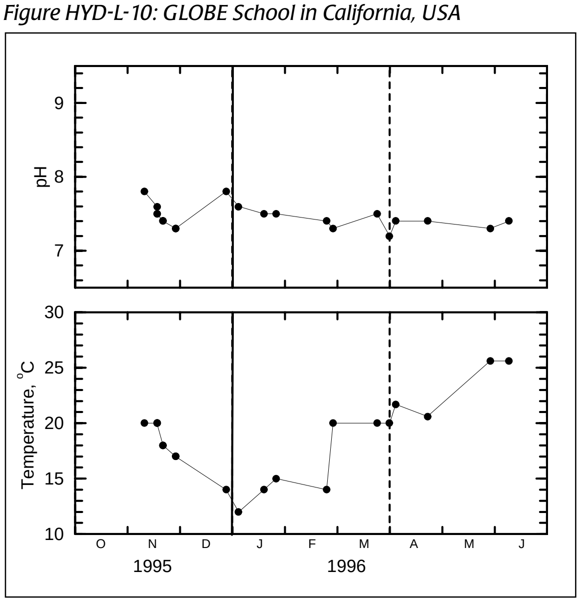


Figure HYD-L-10: GLOBE School in California, USA



Note from the scientists

In the Figure HYD-L-9 we can see that this school is probably making pH measurements using pH paper. This explains the high number of jumps of 1 unit in pH with time. It is entirely possible that the actual pH of the water source being measured by this school in the Midwestern United States is somewhere between pH 7 and pH 8. We would expect slight changes in water pH to push the readings back and forth between two values if they are being made with pH paper.

In Figure HYD-L-10, we see an example of a GLOBE school that is using a pH meter to conduct their measurements. The temperature data show a reasonably smooth temperature progression.

Further Investigations

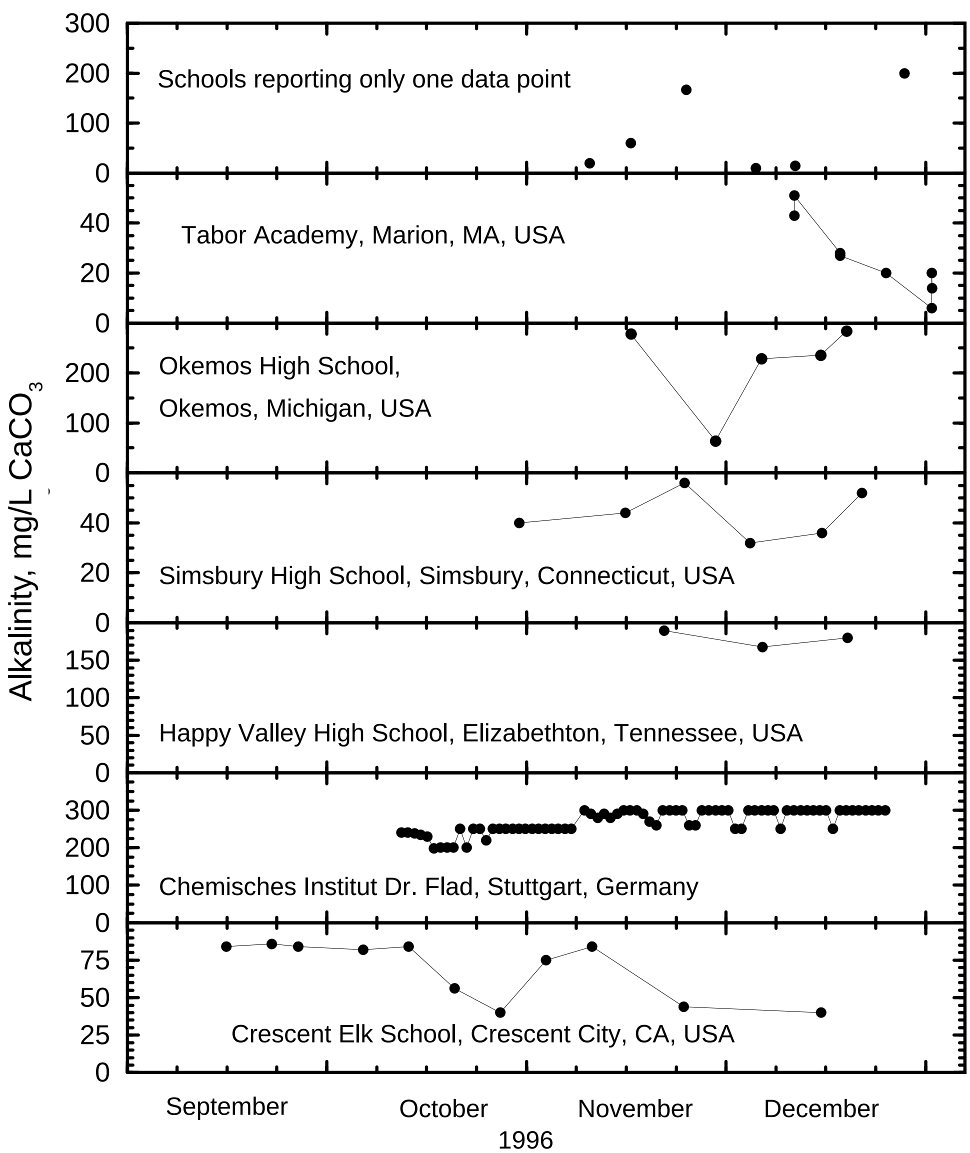
1. Have students recreate the bottom pH graph as if they were using pH paper by taking each point to the nearest whole number and redrawing the graph.
2. Can trends be identified as easily on the old graph as on the new one?

Section 2 - Analysis of New GLOBE Data

Alkalinity was added as a Hydrology protocol in September of 1996. These are a few findings from analysis of some of the earliest schools reporting these data.

1. Have students examine the data from the graphs. How do the data differ?
2. Have students pose questions generated from their observations. For example:
   - What is the data trend? Would you expect it to change seasonally?
   - Do the data seem to be within a normal range?
   - Are there any unusual data points?
3. Have students predict further trends in the data sets.
4. Record the observations, questions, and predictions.
5. Have students devise ways to answer their questions.

Figure HYD-L-11: GLOBE Alkalinity Data, September-December 1996



Note from the scientists

Crescent City, CA, USA is reporting relatively low alkalinity values that exhibit quite a bit of variation with time. These changes could be associated with rainfall, which lowers alkalinity. It will be interesting to put these together with other GLOBE hydrology and atmosphere data for the site in order to gain a more complete picture.

Stuttgart, Germany has a very nice time series that captures even day-to-day changes in alkalinity. They see a slight increase in early November, but otherwise relatively steady values. These relatively high values are from a well-buffered surface water. Again, day-to-day changes could be associated with rainfall.

Elizabethton, TN, USA. Values are intermediate, between those for Crescent Elk School and Chemisches Institut, and are quite consistent with each other. We will be eager to see if alkalinity changes through the winter and into spring.

Simsbury, CT, USA is also reporting relatively low alkalinity values that exhibit some variation with time. In fact, it is surprising that the changes with time are so small, given the range reported. It will be interesting to see if values drop lower during rainfall or snowmelt.

Okemos, MI, USA is reporting alkalinity values that show an interesting drop from nearly 300 mg/L down to about 70 mg/L. We will need to put this together with the other GLOBE hydrology, soil and atmosphere data for the site in order to gain a more-complete picture of what happened.

Marion, MA, USA. Their values are very low and show a steady decline with time. We recommend that they double check their calculations, which if correct show a quite interesting pattern. Are we seeing the effects of tides at this coastal site?

Electrical Conductivity was added as a Hydrology protocol in September of 1996. These are a few findings from analysis of some of the earliest schools reporting these data.

1. Have students examine the data from the graphs. How do the data differ?
   - What is the range of the data within one site?
   - What is the range of data encompassing all sites?
   - What are the data trends? Up? Down? Constant?
2. Have students pose questions generated from their observations.
3. Have students predict further trends in the data sets.
4. Record the observations, questions, and predictions.
5. Have students devise ways to answer their questions by generating hypotheses and justify or support their hypotheses.

Note from the scientists

Belton, TX, USA reports two entries of conductivity measurements from their water site. Both are at very normal levels for a stream system (700 µS/cm, and 745 µS/cm) It will be interesting to see what data show up in the future!

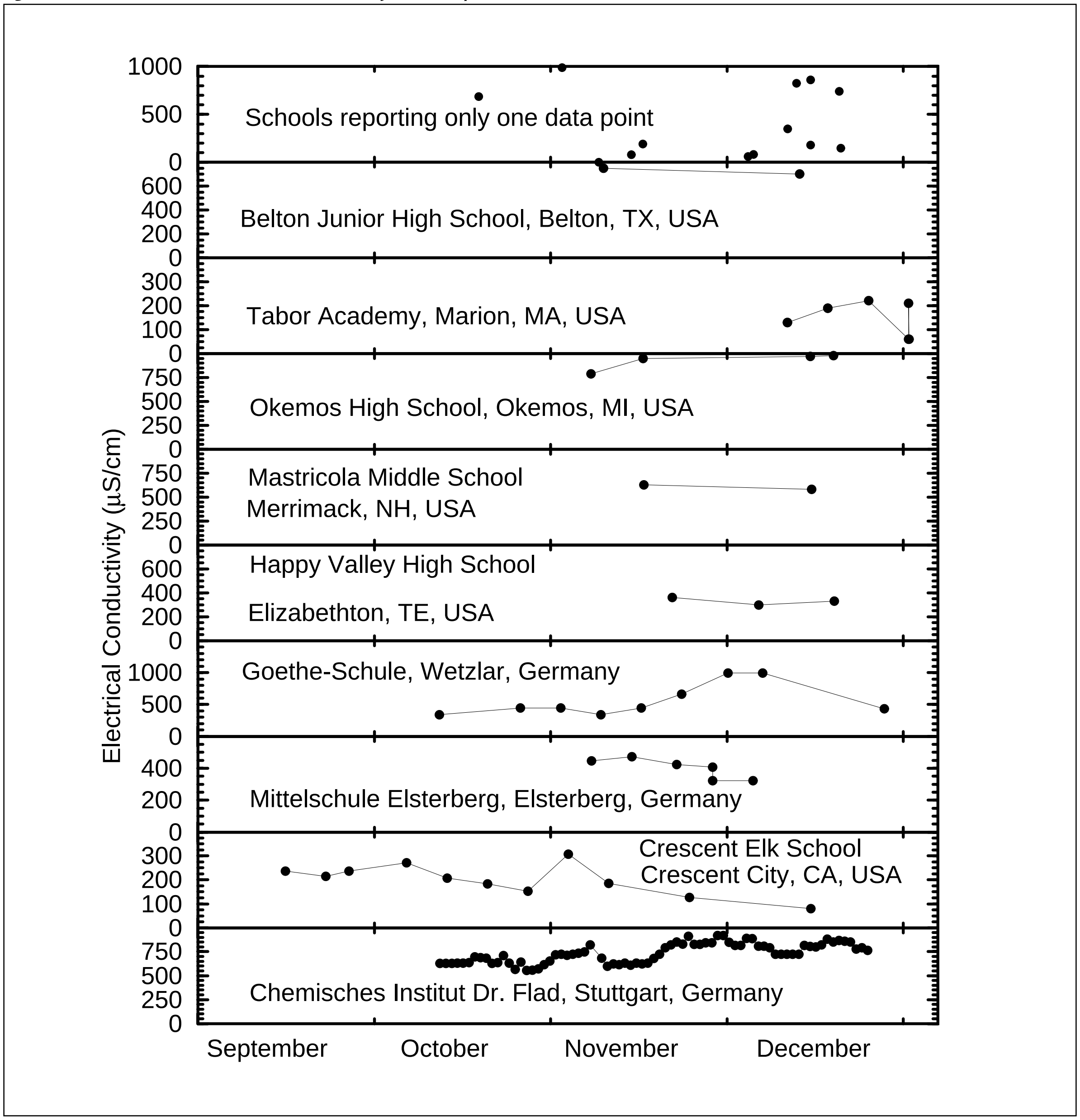
Marion, MA, USA has discovered that their water site consists of relatively pure water with a fairly low conductivity range of 60 µS/cm - 22 µS/cm thus far. Compare these results to what Okemos High School reports and you'll see what a range of impurity levels natural water systems can have!

Okemos, MI, USA measured conductivity with a range of 790 µS/cm - 980 µS/cm! This means that their water is fairly consistently full of dissolved chemicals.

Merrimack, NH, USA has reported 2 conductivity entries, 590 and 630 µS/cm. Look at the other graphs and see where this school falls relatively. What would this indicate about the water? Keep in mind that electrical conductivity is an indicator of what ions are dissolved in the water, and may thus describe the rocks through which the water has flowed.

Elizabethton, TN, USA measures their electrical conductivity in a water source with relatively consistent and low values of conductivity (range: 300 µS/cm - 360 µS/cm) We encourage this school to continue reporting data so we know more about what the water is like in Tennessee and how it changes over the course of the year!

Figure HYD-L-12: GLOBE Electrical Conductivity Data, September-December 1996



Wetzlar, Germany shows the biggest range of measurements of any of the schools we looked at. (Range: 339 µS/cm - 993 µS/cm) They are regularly reporting data every two weeks or so and have found an exciting trend at their site! Over the course of about a month, their conductivity measurements began to climb. What could have caused this change in water chemistry?

Elsterberg, Germany shows that their hydrology water system is fairly consistent in terms of the levels of impurities measured. Their conductivity measurements range from 322 µS/cm to 472 µS/cm. Over the course of their measurements, we see that there has been a slow decline in measured conductivity. What might be causing this?

Crescent City, CA, USA has been reporting data consistently over the 3 month period. Their conductivity measurements appear fairly low. We think we see a gently downsloping trend to the data. Do you? Compare the alkalinity trends and rainfall data to the electrical conductivity trends in Crescent City, USA. Do you see any patterns?

Stuttgart, Germany has developed a real reputation among the hydrology team for reporting many data points. Their conductivity measurements are no exception, and show that their water system changes not only over the course of the three month period of time, but also on a daily basis. Their data range all the way from 552 µS/cm to 920 µS/cm. We think we see evidence for individual storm events in the data here, and possibly a seasonal trend in the levels of impurities. Do you agree? How do these trends compare to rainfall and alkalinity patterns?

Dissolved Oxygen was added as a Hydrology protocol in September of 1996. These are a few findings from analysis of some of the earliest schools reporting these data.

1. Have students examine the data from the graphs in Figure HYD-L-13.
   - How do the data differ?
   - What is the range at different sites?
   - What is the trend in the data?
   - Do all of the data seem to be within normal range? What other information should you consider when judging 'normal range' for dissolved oxygen?
2. Have students pose questions generated from their observations.
3. Have students predict further trends in the data sets.
4. Record the observations, questions, and predictions.
5. Have students devise ways to answer their questions.

Note from the scientists

Belton, TX, USA reported two data points at a level of 9 mg/L. This amount of dissolved oxygen suggests a healthy water source in which fish and plants can live. We encourage Belton to continue making dissolved oxygen measurements, to see how their levels change in the winter and spring.

Marion, MA, USA is measuring a water source where the dissolved oxygen levels are around 10 - 11 mg/L. This range of oxygen levels is supersaturated for a temperature range above 11° C at 0 m. elevation. At the same time that Tabor recorded these DO measurements, they recorded temperatures in a range of 6-8° C. What could cause DO levels to get so high?

Simsbury, CT, USA Simsbury High School reports that their water showed levels of dissolved oxygen at 11 mg/L during October and a sharp rise to a level of 14 mg/L in mid-November. The dissolved oxygen measurements are very consistent until the last entry. We would very much like to know why the last entry is higher. Temperatures measured by Simsbury HS ranged from 1-9° C during this time. On a cautioning note, the recorded temperature when Simsbury HS measured 14 mg/L dissolved oxygen, was 3° C. This DO measurement is supersaturated for this temperature. This suggests that the calibration of Simsbury's dissolved oxygen kit may be off.

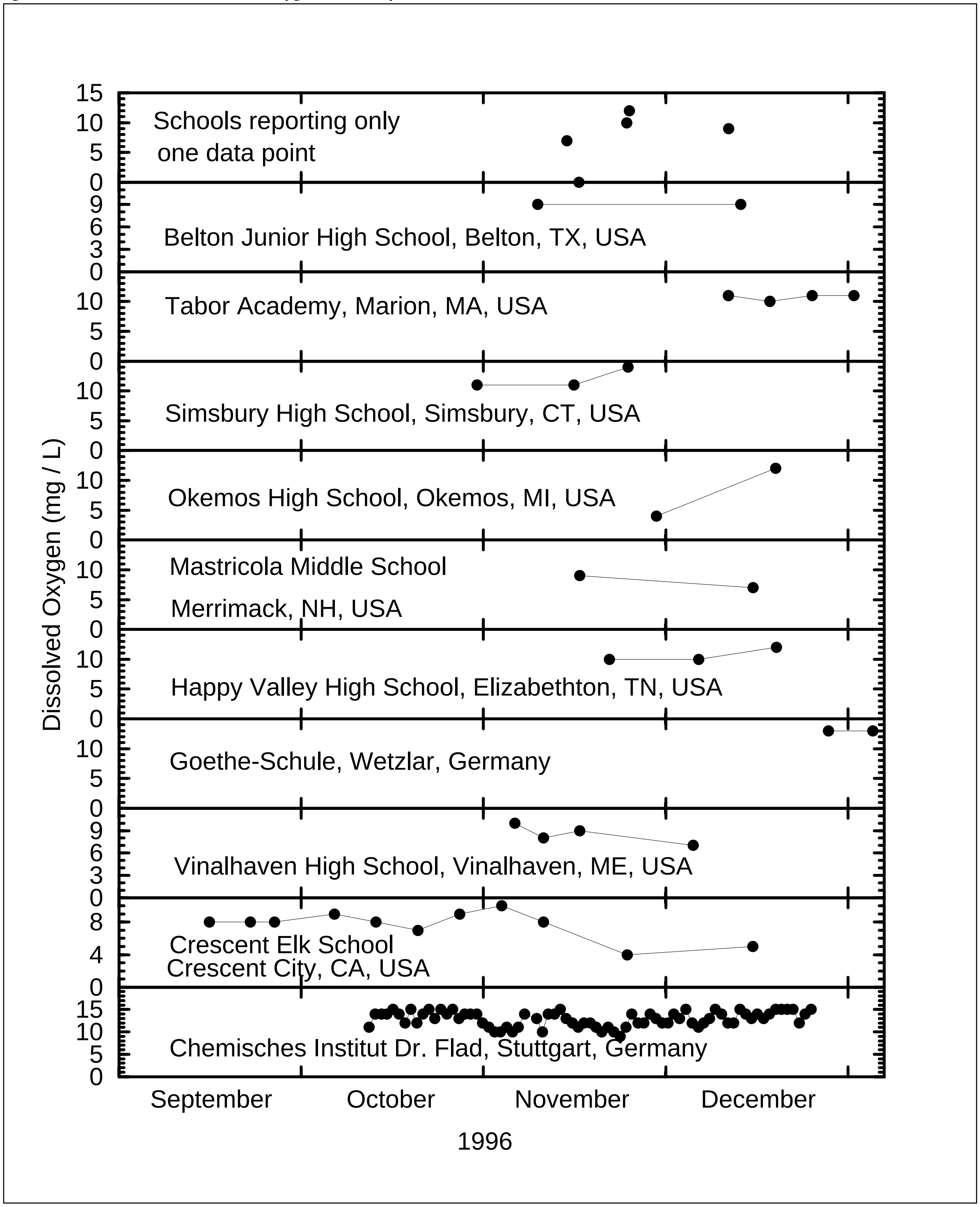
Okemos, MI, USA displays a surprising jump from 4 to 12 mg/L in their DO measurements. Once a careful calibration of equipment used for taking measurements has been done, we propose that if this trend is correct, it might reflect a combination of a drop in water temperature and a drop in the level of biological oxygen demand during the winter.

Merrimack, NH, USA shows a drop in DO from 9 to 7 mg/L over a month period of time, November - December. This drop may represent something interesting in this watershed and we think it is important for the school to think about what may be causing this drop.

Elizabethton, TN, USA measures in their water dissolved oxygen levels that range from 10 to 12 mg/L over a period of about a month. This may be the result of a decrease in water temperature or it may reflect something else. It will be interesting to compare water temperature records with these measurements.

Wetzlar, Germany reports two entries that indicate that their water site possesses fairly high levels of dissolved oxygen (13 mg/L). It is interesting to note that 13 mg/L DO at the temperature recorded, 3.8° C, is very near to saturated. This water source is probably actively mixed with the surrounding air.

Figure HYD-L-13: GLOBE Dissolved Oxygen Data, September-December 1996



Vinalhaven Island, ME, USA initially measured DO levels as high as 10 mg/L but then note a downward trend in their DO over the course of the next month and a half, when they measured it at 7 mg/L. What might cause this kind of drop in oxygen levels? Perhaps certain types of algae that produce oxygen during earlier times of the year begin to die off about this time, and cease to produce oxygen. Another possibility is that the DO level is coming back down from some episode that substantially increased the oxygen level.

Crescent City, CA, USA measures their data on a very regular basis and the data show the changes that take place in their site on a bi-weekly basis. Their oxygen levels gradually go up and down over a range of about 5 to 10 mg/L. It is interesting to note what appears to be an overall decline in dissolved oxygen levels during the 3 month time span shown. This would lead an observer to speculate that the DO levels are decreasing as water temperatures decrease. But does this make sense? Not really, since we would expect DO levels to increase with a decrease in water temperature since cold water can hold more dissolved oxygen than warm water. What might account for this trend? The DO trends follow the conductivity and alkalinity trends. As scientists, we would like to know information about what plant and rainfall activity has occurred over this time period, and about how water discharge levels have changed over this period of time.

Stuttgart, Germany shows the most frequent and consistent series of measurements of the GLOBE schools. They show that dissolved oxygen levels in their area fluctuate over a range of about 10 to 18 mg/L. While trying to figure out what might have produced such high DO measurements, the hydrology team realized that Stuttgart does not always record temperature measurements with their dissolved oxygen entries. Since DO is so temperature dependent, we strongly recommend that schools report water temperature if they measure dissolved oxygen.

Continuing Your Data Analysis

Read the data reports from the Hydrology Investigation on the GLOBE Student Server at the Scientist's Corner. These reports will be updated periodically.

Further Investigations

1. Encourage students to retrieve the current data sets for the schools above and graph the data using the GLOBE graphing tools or import the data into a spreadsheet to graph. What questions were answered by the longer term data set?
2. What questions require other data, such as temperatures or precipitation, to answer. Have students identify data which they think might be relevant and compare it with the Hydrology data. This might include:
   - Does examining soil characterization data help to explain conductivity?
   - What is the relationship between temperature and dissolved oxygen? Are other measurements correlated with temperature?
   - Do dissolved oxygen levels show seasonal fluctuations? What other data fluctuate seasonally?
   - Examine changes in pH at schools with differing levels of alkalinity. Do pH values fluctuate more at sites with high or low levels of alkalinity?
   - Graph precipitation for your site. What hydrology measures changed when you had heavy precipitation? Use the GLOBE contour or point maps to identify other areas showing heavy precipitation for a recent date. What happens to the water chemistry measurements at these sites after the rain?

Were further questions generated by the longer term of data collection? Record these questions and encourage students to come up with methodologies for further research.

Suggestions: Use the GLOBE maps to identify sites with similar latitudes for comparison. Identify 'control sites', or sites which are similar to the one you are investigating except for the variable you are interested in. For instance:

1. Use GLOBEMail to ask questions about site information not reported to the GLOBE data server and to share research with other schools.
2. Use the graphing capabilities of the GLOBE graphing tools to graph data from 2 schools for comparison
3. Use topographic maps to identify watersheds. Zoom into the region you identify in the GLOBE visualizations and find GLOBE sites contained in that watershed. Graph water chemistry data from sites within the watershed to try to identify changes along the course of the waterway.

As more data are added to the GLOBE Student Data Server, continue to identify schools which are of interest to you. Find schools in locations similar to your own. Are their hydrology data similar to yours?

Ask students to critically examine their own data using maps and graphs to look for patterns or unusual data. Ask questions, identify ways to explore their data for answers, and begin to explore their own site.

Student Assessment

Students should be able to identify trends, anomalies and problems with data sets. This capability can be demonstrated in class discussions and by providing them with examples of graphs and asking them to explain the trends, anomalies and issues which they come up with by analyzing the data as a written exercise. They should also be able to demonstrate an understanding of the limitation of what can be understood from a data set. They should be able to use the GLOBE graphing tools to create graphs and analyze data that they find and prepare. Through this activity the students should also gain an understanding of the GLOBE measurement parameters such as pH, temperature and alkalinity. The science content understanding can be assessed in the context of the assessment of the student's understanding of the science of data sets.

Macroinvertebrate Discovery

Purpose

To determine the diversity of benthic (bottom dwelling) macroinvertebrates at your Hydrology Study Site and to investigate the correlations between macroinvertebrates and water chemistry measurements.

Overview

Students will establish a diversity index for benthic macroinvertebrates by sorting and counting organisms collected from the site, and in the process become familiar with many taxa of macroinvertebrates. They will then investigate the relationship between the taxa they found and their water chemistry measurements.

Time

One class period to do the practice exercise

One class period to collect sample and one class period to do the counts and calculate the index

Level

All

Key Concepts

Species diversity is related to water chemistry
Species have different habitat requirements
Random sampling can be used to determine species diversity

Skills

Calculating a diversity index
Performing a random sample
Building tools
Identifying taxa
Discovering species habitat parameters
Taking water chemistry measurements

Materials and Tools

For Practice Activity

Shallow, white tray or pan (such as a styrofoam meat tray) - about 60 X 40 cm
Black marker
Ruler
Small candies, cake decoration confetti, or other items of varying colors or shapes to sample
Macroinvertebrate Work Sheet
Ice cube tray for sorting taxa
Small pieces of paper numbered from 1-50 for drawing random numbers

For Field Activity

Sorting and sampling kit (3 sets needed)
- Shallow white pan for sorting, about 30 x 20 cm
- Shallow white tray for counting, about 60 x 40 cm
- Black permanent marker
- Ice cube tray for sorting taxa
- 10-20 mL bulb basting syringe (end should be approximately 5 mm diameter)
- Large plastic forceps

Magnifying glass
3 mL Pasteur pipette (eye dropper) (end should be approximately 2 mm diameter)
4-L sample container with lid (or 4 1-L containers)
Set of numbered tiles or paper
Bucket for pouring water through net
Additional containers with lids if macroinvertebrates are to be brought back to the classroom
Macroinvertebrate Work Sheet

And either:

kick screen (for running water, rocky bottom sites)

91 x 122 cm nylon screen(2 mm mesh size)

2 poles (122 cm long, 1-2 cm dia)

staples

2 pieces of denim or other heavy fabric (8 x 122 cm each)

needle and thread or heavy waterproof tape

or

D-net (for muddy bottom, still water)

2 pieces of nylon window screen (36 x 53 cm)

3 wire coat hangers

Heavy denim or fabric (8 x 91 cm)

Needle and thread or heavy waterproof tape

152 cm pole (e.g. broom or rake handle)

4 cm pipe clamp

Preparation

Make or buy appropriate net.

Copy Macroinvertebrate Work Sheets.

Collect materials for Sampling Kits.

Collect pictures or books illustrating local macroinvertebrates.

Prerequisites

Students should begin collecting GLOBE water chemistry data.

Background

Benthic macroinvertebrates are small, spineless animals that can be seen without a microscope, generally larger than one mm, which live in the mud or gravel in the bottom of water bodies. These include many larva of insects such as mosquitoes, dragonflies and caddisflies which begin their lives in the water then become land-dwelling insects when they mature. Other examples of common benthic macroinvertebrates include crustaceans such as crayfish, snails, and worms and leeches. These creatures populate the mud or gravel at the bottom of ponds or streams in amazing numbers - often thousands in a square meter. They are often an important part of the food chain.

Macroinvertebrates can tell us a lot about the conditions within a water body. Many macroinvertebrates are sensitive to changes in pH, dissolved oxygen, temperature, salinity, and other habitat parameters. A particular organism requires a consistent water quality to live its full life span.

For the *Macroinvertebrate Discovery* activity we want to establish a diversity index for your hydrology site. Biological diversity is a measure of the number of different kinds of organisms in an ecosystem. It is not a measure of the total number of organisms in the system. For example, you might have an equal number of organisms in a stream with low pH as in a stream with a more neutral pH. But because some types (taxa) of macroinvertebrates would not survive in the low pH stream, the diversity, or total number of different taxa, would be less. You might simply have a larger number of the organisms within each of the taxa which were tolerant of low pH.

What to Do and How to Do It

There are a number of good resources for identifying and researching macroinvertebrates. You will find some of these listed at the end of this activity.

1. Have students investigate the conditions under which different macroinvertebrates live. They may use their own observations, outside references, or the tables at the end of this investigation.
2. Have students form hypotheses on what macroinvertebrates they may find at their water site during the current season. Have them record their research, hypotheses and justification in their GLOBE Science Notebooks. They may want to sketch some of the common macroinvertebrates in their notebooks with notes on identification for field reference.

Calculating the Diversity of Macroinvertebrates in the Field

Preparation

Gather materials for sampling and doing the diversity index. If necessary, make a sampling net using the instructions given at the end of this activity. **Note:** There are two methods to collect your macroinvertebrate sample, depending upon your water site. If you have a rocky/gravel substrate with a current then you should use a Kick Screen. If you have a site with a muddy bottom with virtually no current then you should use a D-Frame net.

Students should do the Practicing the Diversity Index Activity at the end of this activity before they go into the field. This will give them practice in going through the exercise and help them to understand the concept of random sampling.

Collecting Y our Sample

Collect the water chemistry measurements for your site. **Note:** Be sure the water is safe to enter and follow appropriate safety procedures with the students in the water.

Using a kick screen to collect sample:

1. Divide class into groups of 3-4 students and give each group a pail, net, and sampling kit.
2. Have each group identify a sample site. Sites should be within a few meters of each other, but represent different regions of the stream; for example a weedy area and a rocky area.
3. Beginning with the group farthest downstream, have one or two people from each group use either their feet and hands or a stick to disturb the bottom material, while 2 people hold the net 1-2 m downstream from the disturbance. The kicking or stirring should last for at least a minute. Also overturn and scrape the undersides of rocks. For safety reasons, if the area of collection is deeper than one-half meter, do not stand in the water.
4. Lift the net from the water by moving the bottom of the net forward along the bottom of the stream in a scooping motion so that nothing escapes from the net. Using 100-200 mL of water from the site, rinse material from the net into the sorting pan.
5. Have two people from each group pick out organisms using basting syringe or forceps and put them into containers filled with sample water.
6. Repeat steps 3-5 for each student group in order to collect a representative sample. **Note:** If sample area is shallow enough, try to get samples from all the way across the area.

Using a D-frame net to collect sample:

1. Divide class into groups of 3-4 students and give each group a pail, net, and sampling kit.
2. Have each group identify a sample site. Sites should be within a few meters of each other, but represent different regions of the stream; for example a weedy area and a rocky area.
3. Have the first group put the net into the water until it reaches the bottom substrate. Use the net to disturb the substrate for about 30 cm. Glide the net across the bottom of the disturbed area for about 30 cm and then bring it back up to the surface.
4. Pull the net out of the water so that nothing falls out. Using 100-200 mL or water from the site, rinse material from the net into the sorting pan.
5. Have two people from each group pick out organisms using basting syringe or forceps and put them into containers filled with sample water.
6. Repeat steps 3-5 for each student group in order to collect a representative sample. **Note**: If sample area is shallow enough, try to get samples from all the way across the area.

Calculating the Diversity Index:

1. Draw a grid on your counting tray of 4 cm squares.
2. Number the squares consecutively.
3. Pour your sample onto the tray more or less equally distributed across the grid in about 1 mm of water.
4. Have one student draw a number.
5. Have another student find that number on the grid and remove one organism using the Pasteur pipette or forceps. Place this organism (organism 1) in a bowl with water. Note: if there is nothing in the square drawn, draw another number.
6. Put an X on your Work Sheet to represent organism 1.
7. Pick organism 2 from the same square, or if there is nothing else in that square draw another number and sample from the new square.
8. Place organism 2 next to organism 1 in the bowl.
9. If organism 2 is the same as organism 1, put an X on the Work Sheet. If organism 2 is different from organism 1, put an O on the Work Sheet.
10. Put organism 1 into one compartment of the ice cube tray or taxa bowls.
11. Pick organism 3 from the same square, or draw a new square if needed.
12. Place organism 3 next to organism 2.
13. If organism 3 is the same as organism 2, put down the same mark on the Work Sheet as you used for organism 2 (X or O). If organism 3 is different from organism 2, put the opposite mark.
14. Place organism 2 into the ice cube tray. If it is the same as organism 1, put it with organism 1. If it is different, put it into a new compartment.
15. Continue to draw random numbers and take samples, recording each sample as X or O, then sorting the taxa into compartments until 50 samples are taken.
16. Count the number of ‘runs’ on your Work Sheet (see example below) and record.
17. Divide the number of runs by the number of organisms counted (50) and record the number on your Work Sheet.
18. Count the number of different taxa in your sample and record.
19. Multiply the two numbers, and record. This is the diversity index.
20. Have students try and identify as many taxa as possible.

Work Sheet Example:

X X O O O X O O X

1——2———3 4——5

In this particular example, there are 5 runs

Further Investigations

1. Students should identify as many macroinvertebrates as possible from their sample.
2. Compare their hypotheses with the actual taxa they identified.
3. Formulate hypotheses on what conditions may cause certain taxa to exist unexpectedly, or why some common taxa may be missing.
4. Use the GLOBE data server to find schools with a hydrology study site similar to your own. Begin by searching for schools within your watershed or at the same latitude and elevation with similar pH, temperature, dissolved oxygen and salinity levels.
5. Use GLOBEMail to contact these schools and ask about the macroinvertebrates they are finding.

Habitat Parameters for Selected Macroinvertebrates

*pH Range for Selected Macroinvertebrates**

TAXA	1 2 3 4 5 6 7 8 9 10 11 12 13 14
mayfly stonefly caddisfly	XXXX XXXX XXXX
snails clams mussels	XXXXXXXXX XXXXXXXXX XXXXXXXXX

* pH ranges 1-6 and 10-14 are unsuitable for most organisms

Temperature Range for Selected Macroinvertebrates

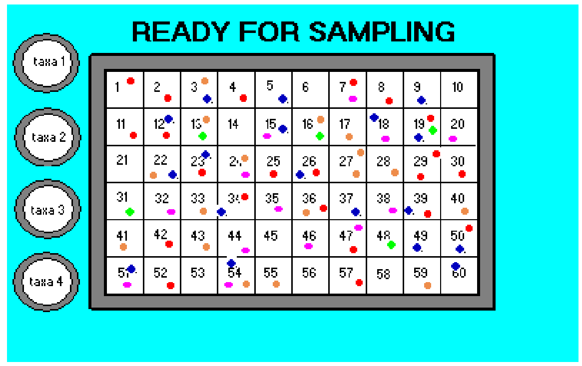
TAXA	Cold Range < 12.8° C	Middle Range 12.8-20° C	Warm Range > 20° C
caddisfly	x	x	x
stonefly	x	x	
mayfly	x	x	
water pennies	x		
water beetles		x	
water striders		x	
dragonfly		x	x

Minimum Dissolved Oxygen Levels for Selected Macroinvertebrates

TAXA	High Range 8 - 10 ppm	Medium Range 4 - 8 ppm	Low Range 0 - 4 ppm
stonefly	X		
water penny	X		
caddisfly	X	X	
some mayflies	X	X	
dragonfly		X	
true bugs		X	
damselfly		X	
mosquito			X
midge			X
tubiflex worm			X
pouch/lung snails			X
rat-tailed maggot			X

Practicing the Diversity Index Activity

1. Draw a grid on your tray of 4 cm squares.
2. Number the squares consecutively.
3. Scatter your sample onto the tray more or less equally distributed across the grid.
4. Have one student draw a number.
5. Have another student find that number on the grid and remove one piece. Place this piece (Sample 1) on the table. If there is nothing in the square, draw another number.
6. Put an X on your Work Sheet to represent Sample 1.
7. Pick Sample 2 from the same square, or if there is nothing else in that square draw another number and sample from the new square.
8. Place Sample 2 next to Sample 1 on the table.
9. If Sample 2 is the same as Sample 1, put an X on the Work Sheet. If Sample 2 is different from Sample 1, put an 0 on the Work Sheet.
10. Put Sample 1 into one of the taxa bowls or cube compartments.
11. Pick Sample 3 from the same square, or draw a new square if needed.
12. Place Sample 3 next to Sample 2.
13. If Sample 3 is the same as Sample 2, put down the same mark on the Work Sheet as you used for Sample 2 (X or 0). If Sample 3 is different from Sample 2, put the opposite mark.
14. Place Sample 2 into a taxa bowl. If it is the same as Sample 1, put it with Sample 1. If it is different, put it into a new taxa bowl.
15. Continue to draw random numbers and take samples, recording each sample as X or 0, then sorting the taxa into bowls until 50 samples are taken.
16. Count the number of 'runs' on your Work Sheet. (See example below.)
17. Divide the number of runs by 50 (your sample number).
18. Multiply this number by the number of different taxa. This is your diversity index.



Further Practice

Have students calculate a Diversity Index using fewer number of taxa or a different distribution of numbers within the taxa. Compare the results.

Work Sheet Example

Record— XX 0 0 0 X 0 0 X

Sample # 1 2 3 4 5 6 7 8 9
Run 1—2——-3 4—5

The example above shows that Sample 1 and 2 were alike. Sample 3 was different from 2. Samples 4 and 5 were like Sample 3. Sample 6 was different from Sample 5, etc. There are 5 runs.

Resources for Research on Freshwater Benthic Macroinvertebrates:

Caduto, M.J. (1990).*Pond and Brook: A Guide to Nature Study in Freshwater Environments*. 2nd ed. Prentice-Hall, NJ.

Cromwell, Mare et al. (1992) I*nvestigating Streams and Rivers.* GREEN, University of Michigan, Ann Arbor.

Maitland, Peter S. (1990). *Biology of Fresh Waters.* Blackie, Glasgow and London.

Merrit, R.E. and K.W. Cummins (1988). *An Introduction to the Aquatic Insects of North America.* Kendall-Hunt Publishing Co., Dubuque, Iowa.

Mitchell, Mark K. and Stapp, William B. (1996). *Field Manual for Water Quality Monitering,* Ann Arbor, Michigan 48104.

McCafferty, P.W. (1981). *Aquaticentomology: The Fishermen's and Ecologist's Guide to Insects and Their Relatives*. Jones and Barlett Publishers, Inc. California.

Needham, James G (1962). *A Guide to the Study of Fresh-Water Biology.* Holden-Day, Inc. San Francisco.

Pennok, Robert. (1973). *Freshwater Invertebrates of the United States.* Ronald Press, NY.

River Watch Network, 153 State St., Montpelier, Vermont 05602.

Save Our Streams, The Izaak Walton League of America, 1800 North Kent Street, Suite 806, Arlington, Virginia 22209.

Video (17 min): *Identification of the Benthic Macroinvertebrates;* Edward A Deschuytner, Northern Essex Community College, Elliott Way, Haverhill, MA 01830-2399.

Instructions for Making Macroinvertebrate Nets

Making the Kick Screen

1. Fold one 8 x 122 cm strip of fabric over one of the long screen edges and sew, reinforcing the edge.
2. Repeat for the other long edge.
3. Attach screen to poles with staples, making the poles even with the bottom of the screen and extending to form handles at the top.
4. Wrap screen around poles several times and staple again to reinforce the edges.

Making the D Net

1. Cut a net shape from the two 36 x 53 cm pieces of nylon screen (see diagrams) and sew them together.
2. Edge the open end of the net with heavy fabric, leaving an opening to form a casing to insert the hanger.
3. Cut hooks from hangers and untwist the wires.
4. Use duct tape to tape the hangers together to make your frame heavier.
5. Insert a wire through the casing and twist ends back together at opening.
6. Drill a hole in the tip of the wooden handle large enough to insert the ends of the hangers. Insert the ends of the hangers into the hole in the pole. Secure the net to the pole by using the hook you cut from the hanger and using the pipe clamp or duct tape to secure the hook to the pole.

Figure HYD-L-14: Making the Kick Screen

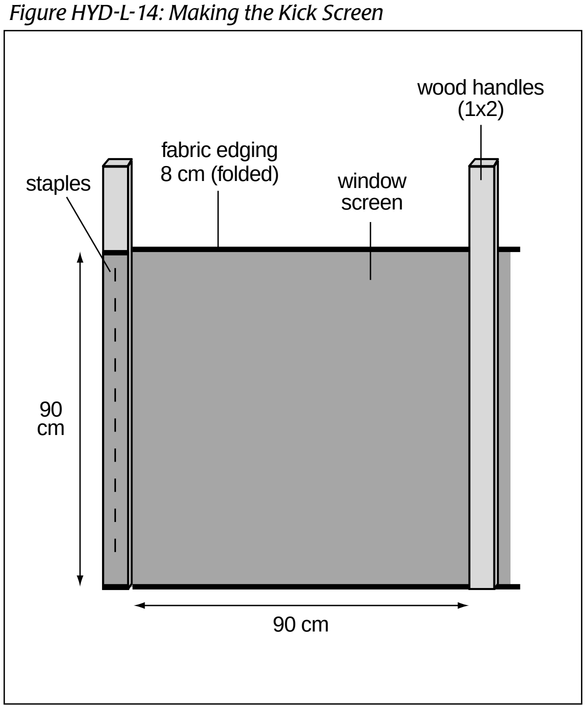
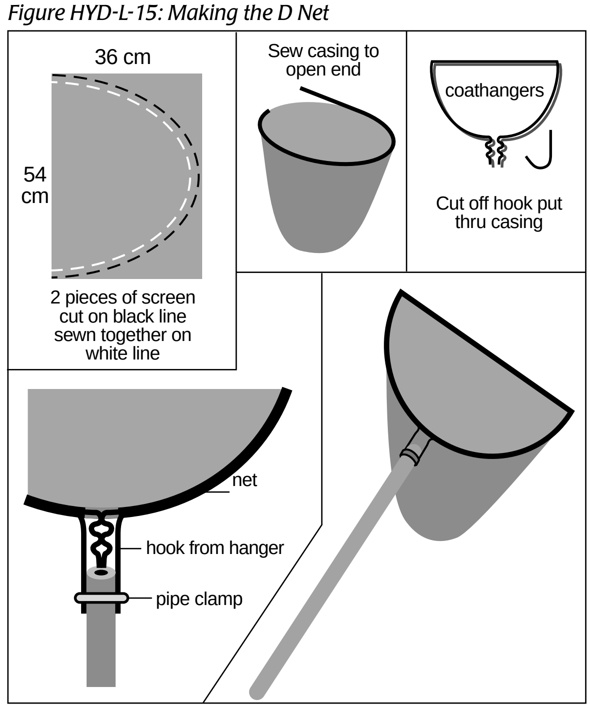


Figure HYD-L-15: Making the D Net



Hydrology Investigation

Macroinvertebrate Activity Work Sheet

Station name: ____

GPS coordinates: Latitude: ____________________ Longitude: ____________________

Collector's name(s): ____

Sample Collection: Sample #: ________ Date: ______________ Time (UT): ______________

Analyst's name(s): ____

Analysis (calculation of diversity index): Date: ______________ Time (UT): ______________

Collecting Method: ________ D net ________ Kick Screen

Calculation of # of runs:

Grid Number

X or 0

Grid Number

X or 0

Total # of Runs ________

Total # of Runs / # Sampled (50) = __________ (Run Index)

Total # of taxa: ________

(Run Index) x (Total # of Taxa) = ___________ (Diversity Index)

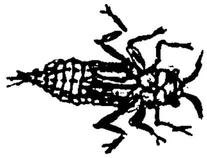
Check Type of Macroinvertebrates Found, if known

Caddisfly (Trichoptera)	Stonefly (Plecoptera)
Mayfly (Ephemeroptera)	True Bugs (Hemiptera)
Worms & Leaches	Snails
Dragonfly/Damselfly (Odonata)	Dobsonfly, Fishfly, Alderfly (Megaloptera)
Beetles (Coleoptera)	Blackfly, Midge, Crane fly, Mosquito (Diptera)
Mites (Arachnids)	Crustaceans (e.g. Sowbug, Scud)

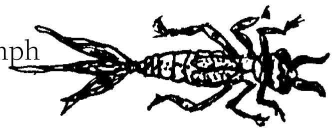
Notes: (water depth, recent rain, rocky, weedy, etc.)

Examples of Macr oinvertebrates

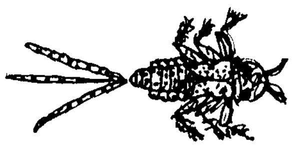
1. dragonfly nymph



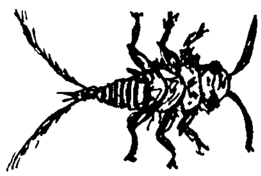
2. damselfly nymph



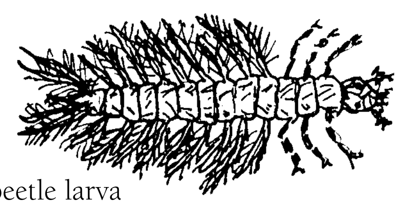
3. mayfly nymph



4. stonefly nymph

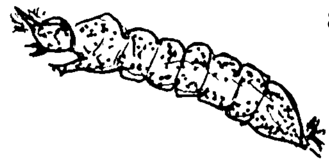


5. caddisfly larva

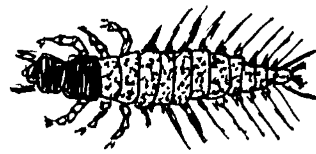


6. whirligig beetle larva

7. aquatic sowbug



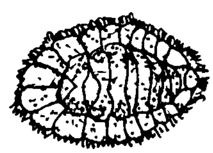
8. blackfly larva



9. dobsonfly larva

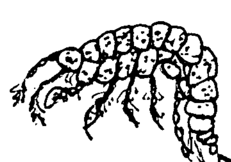
10. midge larvae

11. crane fly larvae



12. water penny beetle larva

13. mosquito



14. scud

Modeling Your Water Balance

Purpose

Use GLOBE temperature, latitude, and precipitation data to model the change in soil water storage over a year's time, then to compare your model with GLOBE soil water content and biometry data.

Overview

Students will create a physical model using glasses to represent the soil column that illustrates the soil water balance. They will use data from the GLOBE Data Server to calculate the potential evapotranspiration (the amount of water needed to meet the demand for the month), average monthly temperatures and precipitation for their model. They will then construct a model representing the soil water balance for their site.

Time

One class period to calculate values

One class period to construct model

One class period for hypothesis testing

Level

Intermediate and advanced

Key Concepts

- Soil stores water.
- Soil has a water holding capacity (field capacity).
- Higher temperatures and longer periods of daylight increase evapotranspiration.
- Precipitation is not equal to the amount of water stored in the soil.
- Soil water content is related to vegetative growth.

Skills

- *Measuring* volume and length
- *Following* directions
- *Building* models
- *Retrieving* data from the GLOBE server
- *Reading* graphs
- *Calculating* averages
- *Testing* hypotheses using models
- *Graphing* GLOBE data

Materials and Tools

- 14 beakers, glasses, or graduated cylinders (approximately 20-25 cm tall, or tall enough to hold the total precipitation for the wettest month at your model site)
- Water (or other medium to represent precipitation such as rice)
- Red and black markers
- Ruler
- Data from example or from GLOBE server

Preparation

For advanced activity: Collect GLOBE temperature, precipitation, GPS, soil moisture, biomass and hydrology data

Prerequisites

Simple math calculations, reading graphs, using GLOBE Data Server

Background

The amount of water stored in the soil at your site can be estimated by conducting a water balance for your area. The water content of your soil varies depending on the balance between water gained due to precipitation and water lost through evaporation and transpiration. The combined amounts of water lost through evaporation and transpiration is called evapotranspiration. The maximum rate of evapotranspiration would occur if water was always available and is called potential evapotranspiration. The water content of your soil is a key factor in determining which plants can grow in your area. Several factors control the water content of your soil including temperature, the duration of sunshine, the amount of groundcover and the amount of precipitation. One might think that the months of highest precipitation would also be the months with the greatest soil water content. This may be true- but maybe not - if the temperatures are so great that most of the water evaporates! Scientists study the water balance in an area to predict when plants will grow and when they will be under stress due to lack of water.

Preparation

Discuss with students the importance of water held in the soil with your student. You may want to do the *Just Passing Through* activity to illustrate the holding capacity of different soils.

Copy the Work Sheets for students to use.

What to Do and How to Do It

Examine the data in Figure HYD-L-16.

Precipitation = total amount of precipitation for the month

Water Needed (PE) = Potential Evapotranspiration is the total amount of water that would be lost through evaporation and transpiration if water was always available.

Extra Water = Precipitation in excess of what is needed

Extra Water Needed = Water needed from storage to make up a shortage in precipitation

Water in Storage = Water stored in soil available for plants (cannot exceed 100 mm, because this is the field capacity for this site)

Water Shortage = Water that is needed in excess of precipitation and ground storage

Runoff = Water which is lost through runoff when precipitation is greater than need and ground storage is at capacity

Temperature = average monthly temperature

Figure HYD-L-16: Water Balance Table, Mt. Lemmon, AZ Practice Data

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Precipitation (mm)	69	23	98	56	9	23	183	71	23	32	68	54	
Water Needed (PE in mm)	13	7	16	33	64	99	101	96	86	60	27	7	
Extra Water													
Extra Water Needed													
Water in Storage													
Water Shortage													
Runoff													
Temperature (avg in Celsius)	2	2	4	8	12	17	18	17	16	12	7	3	

1. Which month has the most precipitation? Which has the least?
2. Which month is the warmest? Which is the coldest?
3. During which months will water needed (PE) exceed precipitation?
4. During which months might you expect to have runoff?
5. Make a hypothesis on which month or months you would expect to have a water shortage. Record your hypothesis and your justification for your hypothesis in you GLOBE Science Notebook.

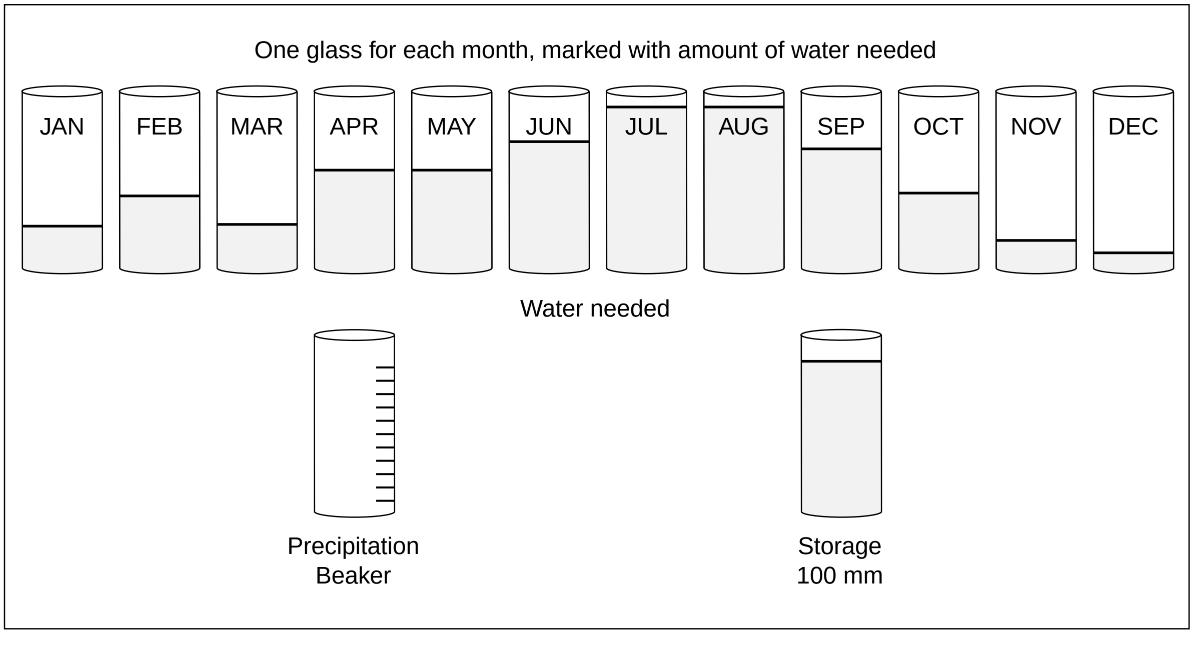
Setting Up Your Model

1. Set out 12 containers representing months of the year. Label them from January through December. See Figure HYD-L-17.
2. Find, in the table, the amount of potential evapotranspiration (PE) that is needed for each month. Draw a line on each container with a marker showing the mm of PE needed for that month.
3. Mark the 13th container as storage. Make a line at 100 mm on the container to indicate when storage is full.

Using Your Model

1. Begin modeling your water balance by measuring in the precipitation beaker the amount of precipitation you received for January. Then follow the procedure below:
   - If you have more precipitation than you need for the month, fill the month container only up to the PE line, then put the extra water from the precipitation beaker into storage.
   - The Storage container can only be filled to the 100 mm level; extra water is runoff and can be thrown away.
   - If you do not have enough precipitation for the month to fill to the PE line, pour all of the precipitation into the month container, then take water from storage and pour it into the month container until you reach the PE line.
   - If you still do not have enough water after pouring in all of the precipitation from the beaker and using all of the storage, make a red line on the glass at the water level to show a water shortage.
2. As you create the water balance model, fill in the Water Balance Table Work Sheet with the appropriate data for each month. (Review the example of the filled in Water Balance Table on the Water Balance Table Work Sheet.)

Figure HYD-L-17: Setting Up for the Water Balance Model



3. Repeat these steps for all of the months. Do the months in order so that you will know how much is in storage each month.

Notes

1. Sand, rice or some other material can be used instead of water.
2. Try starting the experiment with January, then start with October. In the U.S. and some other areas, hydrologists define a "water year" as starting in October, before the winter snow accumulation season. Do you get a different result?

Discuss Your Results:

1. Which months show a water shortage? Did this agree with your hypothesis? Are there any variables which you might now take into consideration in forming a hypothesis on water shortages at a site?
2. Are water shortages always in months with the least precipitation?
3. Are water shortages always in months with the highest temperatures?
4. During which months might you expect floods? Justify your hypothesis.

Testing Other Hypotheses With Your Model

Form hypotheses predicting how the water balance will change with changes in the variables

1. What happens if you have a particularly wet winter? (increase the winter precipitation)
2. What happens if you have an unusually dry summer? (decrease the summer precipitation)
3. What happens if you have an unusually hot summer (increase the water needed (PE) for the summer months)
4. What happens if you increase your storage through building an artificial reservoir? (increase Storage to 150 mm)

Test your hypotheses by changing the variables in the table and running the model again.

Adaptation for Older Students

Have students complete the Water Balance Table Work Sheet for their own or another site using GLOBE data.

1. Find the average monthly precipitation for each month and fill in the precipitation row in the table.
2. Find the average monthly temperature for each month and fill in the temperature row in the table.
3. Find the latitude for your site and fill in the latitude.
4. Find the PE for each month and fill in the PE row in the table. (PE may be calculated using the Calculating the PE Work Sheet in the appendix)
5. Find the difference between the precipitation and the water needed (PE) for the month.

- If there is more water than needed, enter the difference in the extra water row.
- Also enter this difference into the water storage row, adding it to any water that is already in Storage from the previous month. **Note:** In the first month you do not have a number to add from the previous month, so just enter the difference.
- Storage cannot be <0 or >100. Put the amount over 100 mm into runoff.
- If there is less water than needed, enter the difference into the extra water needed row.
- Subtract (water in storage from the previous month) - (extra water needed from the current month).
- Enter this number into the current month water storage box if it is >0.
- If the number is <0, enter 0 in the water storage box and your answer into the water shortage box.

6. Students should also calculate the actual amount of water loss through evapotranspiration:

   If Precipitation > PE:

   Actual Evapotranspiration = PE

   If precipitation < PE (as long as there is water in storage):

   Actual Evapotranspiration =

   Precipitation + extra water needed

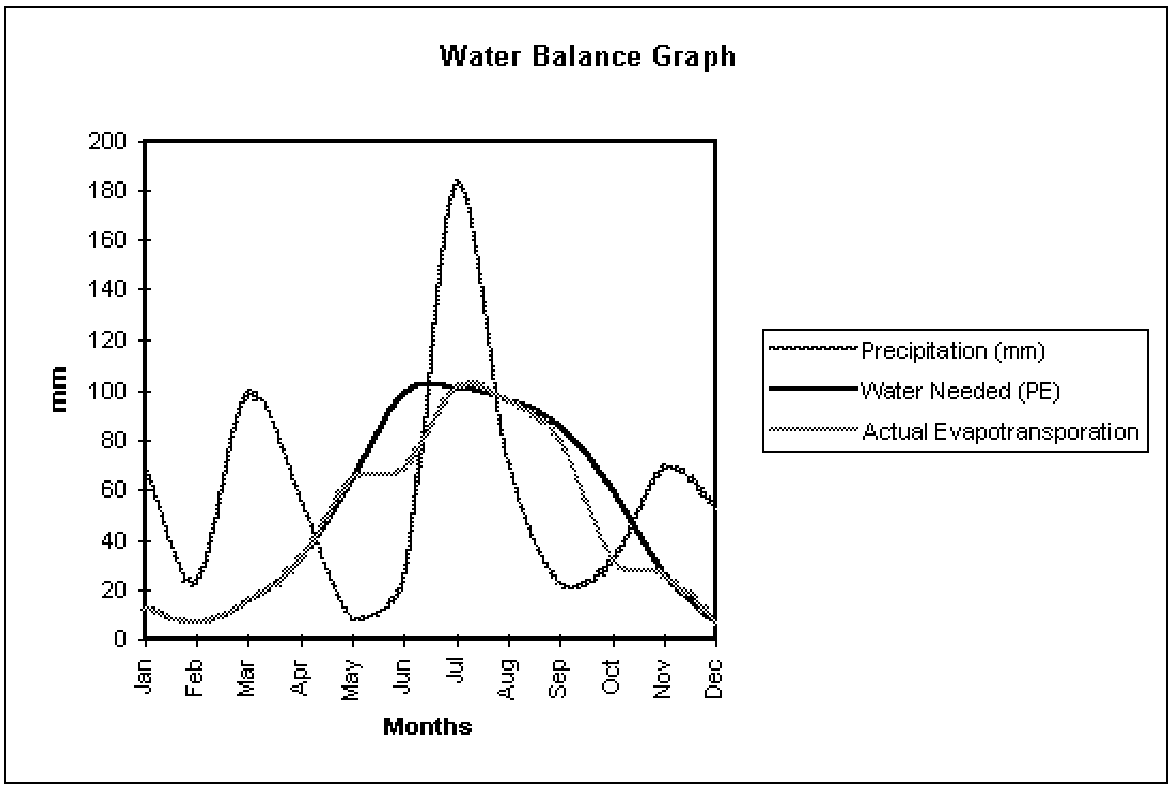
   You can only add the amount of water that is available in storage.

Graph the precipitation, actual evapotranspiration, and PE (3 lines) for the site on one graph using the months on the X axis, and mm of water on the Y axis for Precipitation, Actual Precipitation. See Figure HYD-L-18. Examine the graph and shade in areas where you have water surplus, water shortage, shortage use and recharge, and runoff.

Form hypotheses on how closely other variables may be correlated with the water balance. Use the GLOBE Data Server to investigate your hypotheses.

1. Examine the GLOBE soil moisture data from the site where you modeled water balance. What correlation can you find between your model and the soil moisture data?
2. Compare the GLOBE biomass data from the site where you model water balance. How closely do they compare? Do times of greatest biomass occur at the times of greatest water availability?
3. Graph your measurements of water chemistry. Are there any indications of changes in water balance which may affect the quality of a water body?

Figure HYD-L-18: Example Graph for Precipitation, Water Needed (PE), and Actual Evapotranspiration



Hydrology Investigation

Water Balance Table Work Sheet

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Precipitation (mm)													
Water Needed (PE in mm)													
Extra Water													
Extra Water Needed													
Water in Storage													
Water Shortage													
Runoff													
Temperature (avg in Celsius)													

Example: Completed Water Balance Table (data from Mt. Lemmon, AZ, USA)

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Precipitation (mm)	69	23	98	56	9	23	183	71	23	32	68	54	
Water Needed (PE in mm)	13	7	16	33	64	99	101	96	86	60	27	7	
Extra Water	56	16	82	23			82				41	47	
Extra Water Needed					55	76		25	63	28			
Water in Storage	56	72	100	100	45	0	82	57	0	0	41	88	
Water Shortage						31			6	28			
Runoff			54	23									
Actual Evapotranspiration	13	7	16	33	64	68	101	96	80	32	27	7	
Temperature (avg in Celsius)	2	2	4	8	12	17	18	17	16	12	7	3	

Hydrology Investigation
Calculating Potential Evapotranspiration Work Sheet

This work sheet will allow you to calculate the Potential Evapotranspiration (PE) for any site using the temperature and latitude data from the GLOBE server. Potential Evapotranspiration may then be used in the Water Balance Activity.

Step 1

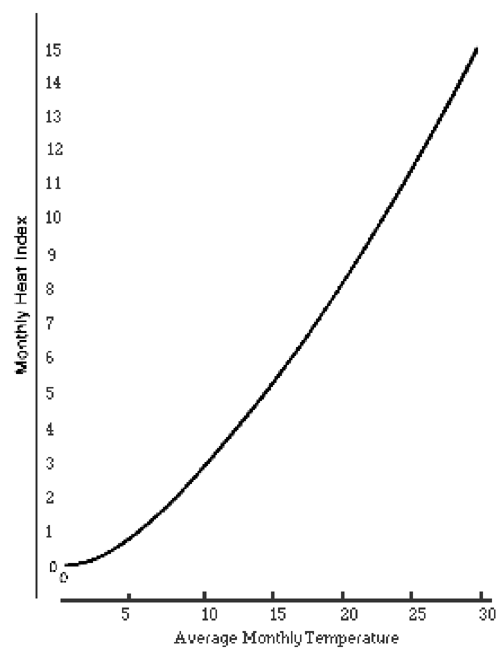
Find the Average Monthly Temperature for your site using the GLOBE data server.

Average Monthly Temperature:

Jan___Feb___Mar___Apr___May___Jun___Jul___Aug___Sep___Oct___Nov___Dec__

Step 2

Find the **Heat Index** for each month from the graph below.



Monthly Heat Index

Jan___Feb___Mar___Apr___May___Jun___Jul___Aug___Sep___Oct___Nov___Dec__

Step 3

Add the Monthly Heat Indexes together to get the Annual Heat Index.

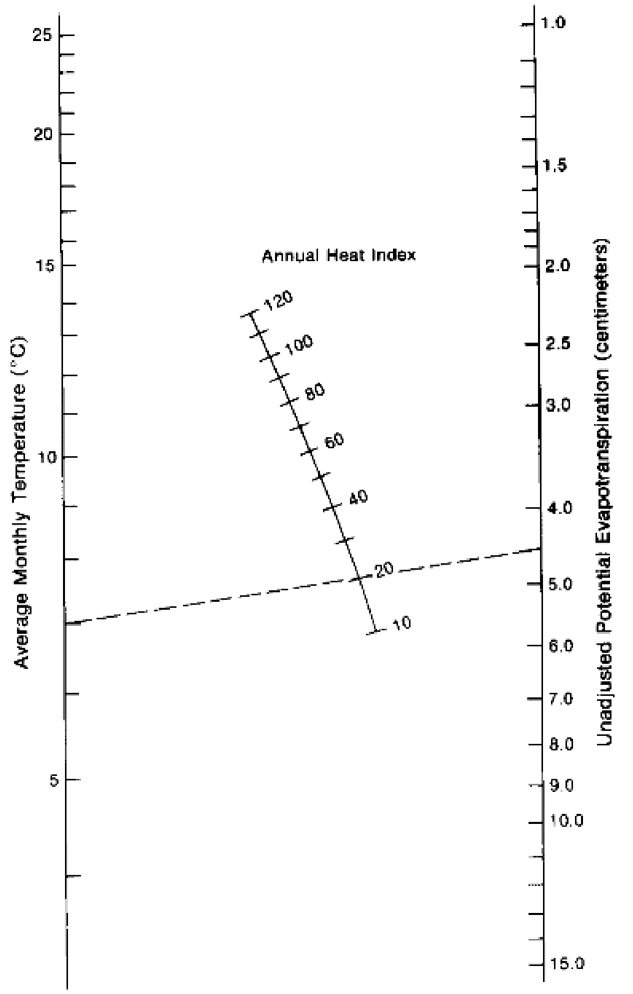
Annual Heat Index:__________

Step 4

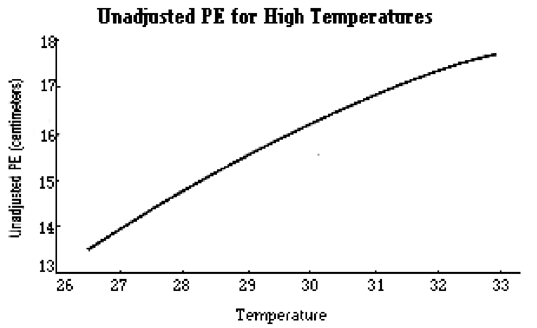
Using the **Annual Heat Index** and the **Average Monthly Temperature** for each month, find the **Unadjusted Potential Evapotranspiration** from the appropriate graph below.

NOTE: If the average temperature for the month is below 0, the Unadjusted Potential Evapotranspiration for that month is 0. If the average temperature for the month is greater than 26.5, use the Unadjusted Potential Evapotranspiration for High Temperatures graph below.

Unadjusted Potential Evapotranspiration



Note: To use the graph above, find your Average Monthly Temperature on the left and your Annual Heat Index in the center. Make a straight line joining the 2 points and continuing on until you cross the Unadjusted Potential Evapotranspiration line on the right. Read your Unadjusted PE from this line and record below. For higher temperatures, use the graph below to read your Unadjusted PE directly from the Temperature.



Unadjusted Potential Evapotranspiration for each month

Jan___Feb___Mar___Apr___May___Jun___Jul___Aug___Sep___Oct___Nov___Dec__

Step 5

Record the **Correction Factor** for each month from the table below.

Jan___Feb___Mar___Apr___May___Jun___Jul___Aug___Sep___Oct___Nov___Dec__

Step 6

Multiply the **Correction Factor** by the **Unadjusted PE** to find the **Potential Evapotranspiration.**

Potential Evapotranspiration

Jan___Feb___Mar___Apr___May___Jun___Jul___Aug___Sep___Oct___Nov___Dec__

Daylight Correction Factors for Potential Evapotranspiration

Latitude	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	1.04	0.94	1.04	1.01	1.04	1.01	1.04	1.04	1.01	1.04	1.01	1.04
10 N	1.00	0.91	1.03	1.03	1.08	1.06	1.08	1.07	1.02	1.02	0.98	0.99
20 N	0.95	0.90	1.03	1.05	1.13	1.11	1.14	1.11	1.02	1.00	0.93	0.94
30 N	0.90	0.87	1.03	1.08	1.18	1.17	1.20	1.14	1.03	0.98	0.89	0.88
40 N	0.84	0.83	1.03	1.11	1.24	1.25	1.27	1.18	1.04	0.96	0.83	0.81
50 N	0.74	0.78	1.02	1.15	1.33	1.36	1.37	1.25	1.06	0.92	0.76	0.70
10 S	1.08	0.97	1.05	0.99	1.01	0.96	1.00	1.01	1.00	1.06	1.05	1.10
20 S	1.14	1.00	1.05	0.97	0.96	0.91	0.95	0.99	1.00	1.08	1.09	1.15
30 S	1.20	1.03	1.06	0.95	0.92	0.85	0.90	0.96	1.00	1.12	1.14	1.21
40 S	1.27	1.06	1.07	0.93	0.86	0.78	0.84	0.92	1.00	1.15	1.20	1.29
50 S	1.37	1.12	1.08	0.89	0.77	0.67	0.74	0.88	0.99	1.19	1.29	1.41

Using the Table: For each month, look up the latitude of the site and the name of the month in the table above to find the Correction Factor for each month.

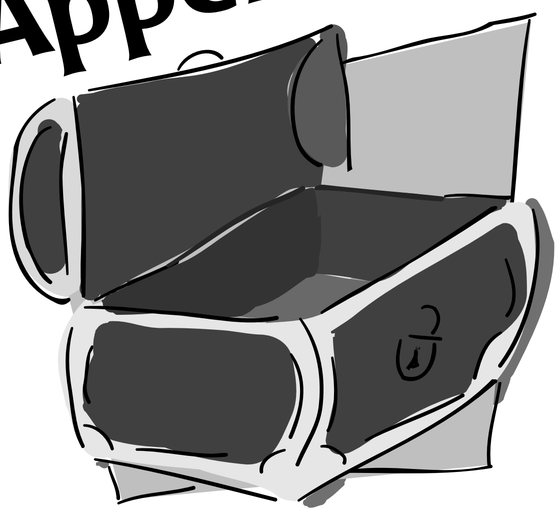
Note: The correction factors for latitude 50 N are used for all latitudes father to the north. The correction factors for latitude 50 S are used for all latitudes farther to the south.

Step 7

Record the PE in the appropriate row of your Water Balance Table.

*Adapted from Muller, Robert A and Oberlander, T. (1978) *Physical Geography Today: A Portrait of a Planet,* Random House.

Appendix



Data Work Sheet

Calibration Data Work Sheet

Contour Line Basics

Graphs for Duplication

Glossary

GLOBE Web Data Entry Sheets

Hydrology Investigation
Data Work Sheet

School name: ______________________________

Student group: ______________________________

Site Name: ______________________________

Sample collection date: ________ time: ________ (hours and minutes) check one: UT___ Local ___

Transparency

Cloud cover (check one): ____ clear ____ scattered ____ broken ____ overcast

Secchi Disk:

Observer 1: Length of rope: when disk disappears: ______ m when disk reappears: ______ m

Distance from where the Observer 1 marked the rope to the Water Surface: ___________ m

Observer 2: Length of rope: when disk disappears: ______ m when disk reappears: ______ m

Distance from where the Observer 2 marked the rope to the Water Surface: ___________ m

Observer 3: Length of rope: when disk disappears: ______ m when disk reappears: ______ m

Distance from where the Observer 3 marked the rope to the Water Surface: ___________ m

Turbidity Tube:

Water line in tube when image disappears:

Observer 1: ______ cm Observer 2: ______ cm Observer 3: ______ cm

Water Temperature

Observer 1: ______ °C Observer 2: ______ °C Observer 3: ______ °C Average: _______°C

Dissolved Oxygen

Observer 1: ______ mg/L Observer 2: ______ mg/L Observer 3: ______ mg/L Average: _______mg/L

Kit manufacturer and model:______________________________

pH

Measurement method: _____paper _____pen _____ meter

Value of buffers at site: pH 4: ______ pH 7: _______ pH 10: ______

Observer 1: ______ Observer 2: ______ Observer 3: ______ Average: _______

Conductivity

Conductivity Standard: _________ MicroSiemens/cm (μS/cm)

Observer 1: _____ μS/cm Observer 2: _____ μS/cm Observer 3: _____ μS/cm Average: ______ μS/cm

Data Work Sheet (page 2)

Salinity

Tide Information

Time of tide before measurement: ________________ hours and minutes

Check one: High Tide ___ Low Tide___ Check one: UT _____ Local time_____

Time of tide after measurement: ________________ hours and minutes

Check one: High Tide ___ Low Tide___ Check one: UT _____ Local time_____

Place where these tides occur: ____

Salinity (Hydrometer Method)

	Observer 1	Observer 2	Observer 3
Temperature of water in the cylinder:	_________ °C	_________ °C	_________ °C
Specific Gravity:	_________	_________	_________
Salinity of Sample:	_________ ppt	_________ ppt	_________ ppt

Average Salinity: _________ ppt

Optional Salinity Titration

Salinity of Sample: Observer 1: _______ ppt Observer 2: _______ ppt Observer 3: _______ ppt

Average Salinity: _______ ppt

Kit manufacturer and model:____

Alkalinity

For kits that read alkalinity directly

Observer 1: ____ mg/L as $CaCO_3$ Observer 2: ____ mg/L as $CaCO_3$ Observer 3: ____ mg/L as $CaCO_3$
Average: _______ mg/L as $CaCO_3$

Hach kits or other kits in which drops are counted:

	Observer 1	Observer 2	Observer 3	Average
Number of drops	________drops	________ drops	________drops	________ drops
Conversion constant for your kit and protocol:	x_______	x_______	x_______	x_______
Total Alkalinity (mg/L as $CaCO_3$)	=_______mg/L	=_____ mg/L	=_______mg/L	=_______ mg/L

Kit manufacturer and model:____

Nitrate

Observer 1: _______ mg/L NO_3^- - N + NO_2^- - N _______ mg/L NO_2^- - N

Observer 2: _______ mg/L NO_3^- - N + NO_2^- - N _______ mg/L NO_2^- - N

Observer 3: _______ mg/L NO_3^- - N + NO_2^- - N _______ mg/L NO_2^- - N

Average: _______ mg/L NO_3^- - N + NO_2^- - N _______ mg/L NO_2^- - N

Kit manufacturer and model:________________________________

Hydrology Investigation

Calibration Data Work Sheet

School name: ____

Student group: ____

Date: ________

Dissolved Oxygen:

Temperature of distilled water: ______C; Elevation of your site: _____meters

Dissolved Oxygen for the shaken distilled water:

Observer 1: _____ mg/L Observer 2: _____ mg/L Observer 3: _____ mg/L Average: ______mg/L

Solubility of oxygen in water for your temperature at sea level from Table 3-1.		Calibration value for your elevation from Table 3-2.		Expected value for DO in your distilled water:
______________mg/L	x	______________	=	_________mg/L

Kit manufacturer and model:____

Salinity

Salinity of Standard: Observer 1: ______ ppt Observer 2: ______ ppt Observer 3: ______ ppt

Average Salinity: ______ ppt

Kit manufacturer and model:____

Alkalinity

For Baking Soda Standard

For kits that read alkalinity directly

Observer 1: ____ mg/L as $CaCO_3$ Observer 2: ____ mg/L as $CaCO_3$ Observer 3: ____ mg/L as $CaCO_3$

Average: ______ mg/L as $CaCO_3$

Hach kits or other kits in which drops are counted:

	Observer 1	Observer 2	Observer 3	Average
Number of drops	_______drops	_______ drops	_______drops	_______ drops
Conversion constant for your kit and protocol:	x______	x______	x______	x______
Total Alkalinity (mg/L as $CaCO_3$)	=______mg/L	=_____ mg/L	=______mg/L	=______ mg/L

Kit manufacturer and model:____

Nitrate

Observer 1: ____ mg/L NO_3^- - N Observer 2: ____ mg/L NO_3^- - N Observer 3: ____ mg/L NO_3^- - N

Average: ____ mg/L NO_3^- - N

Kit manufacturer and model:____

Contour Line Basics

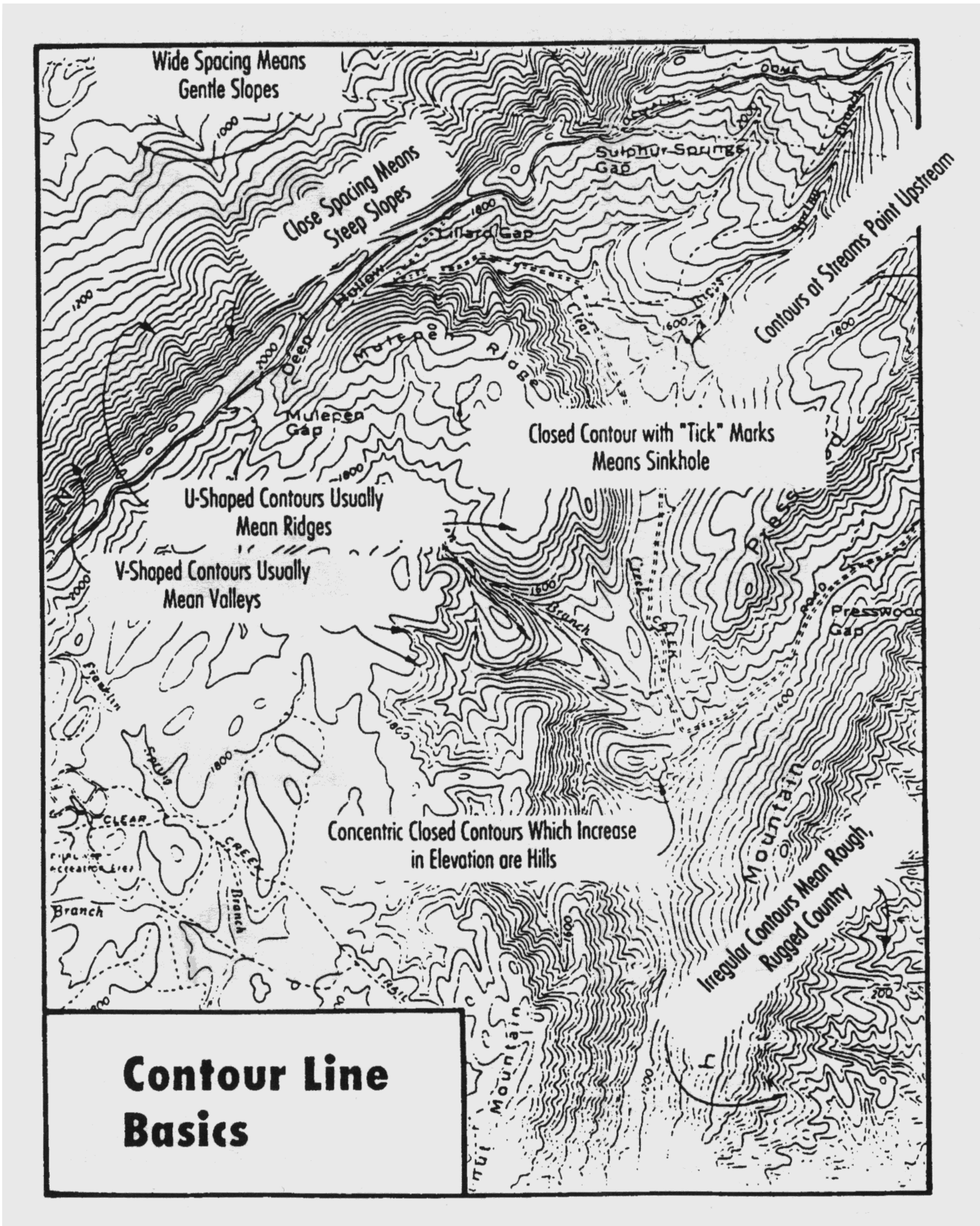
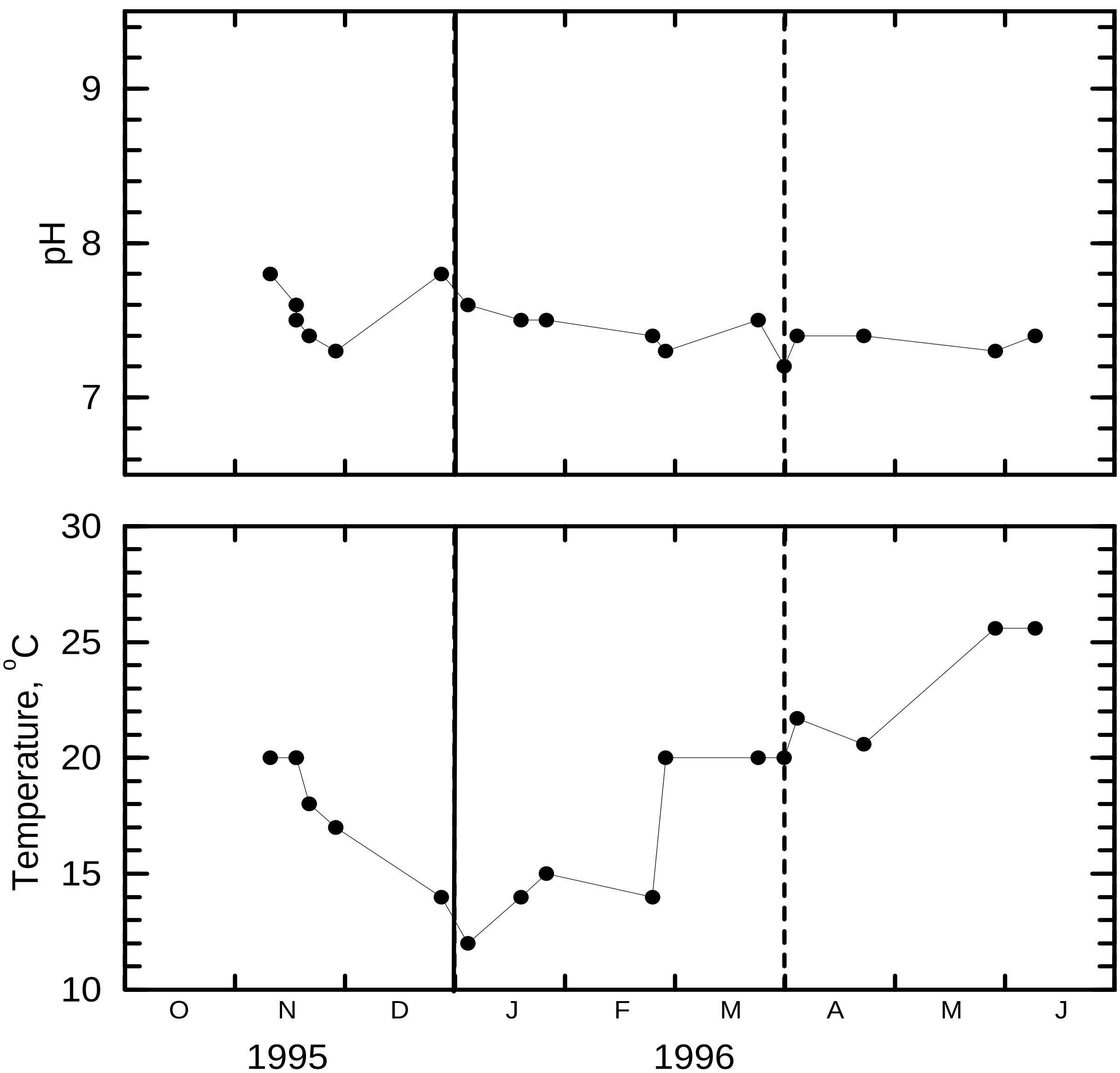
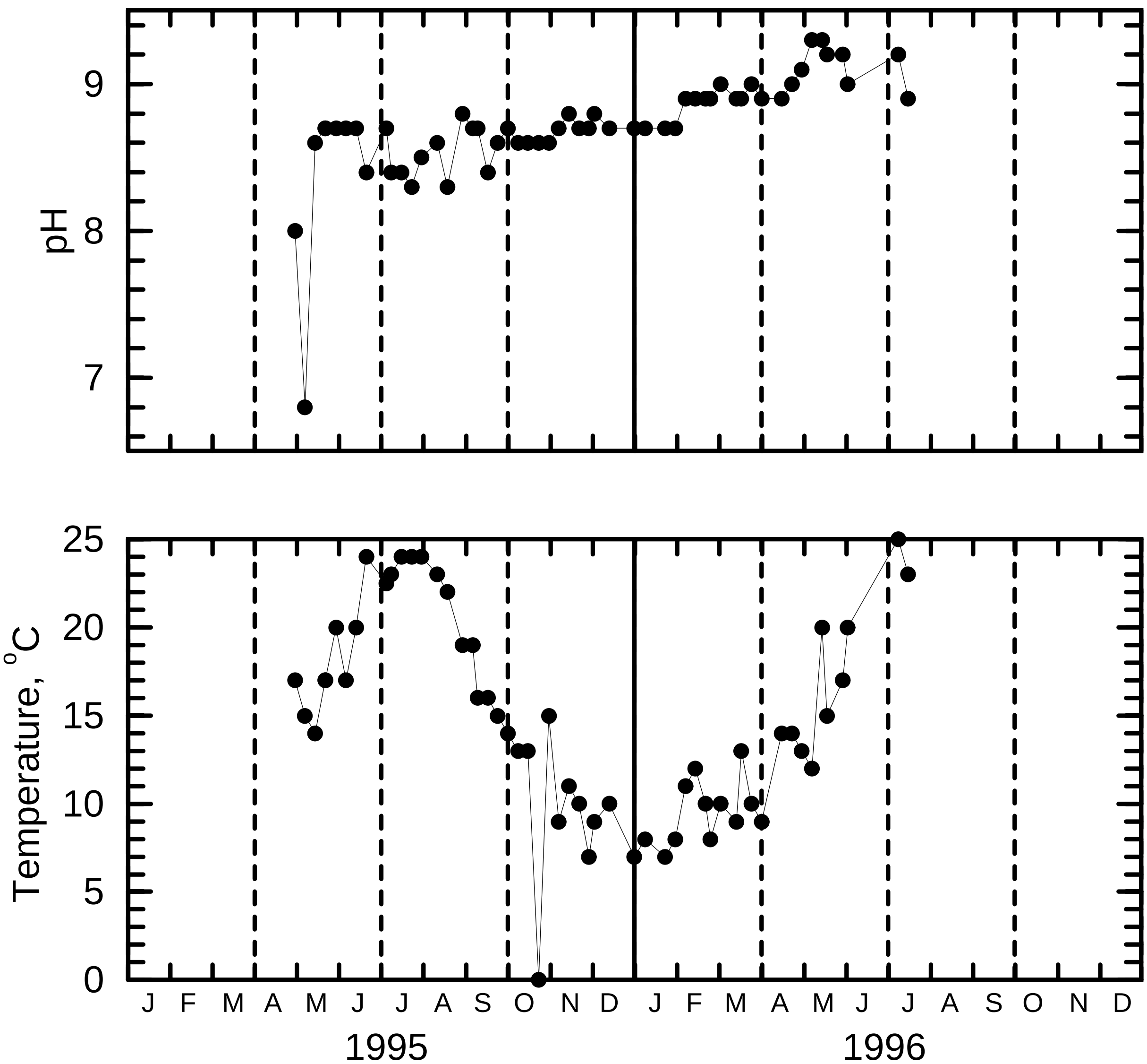


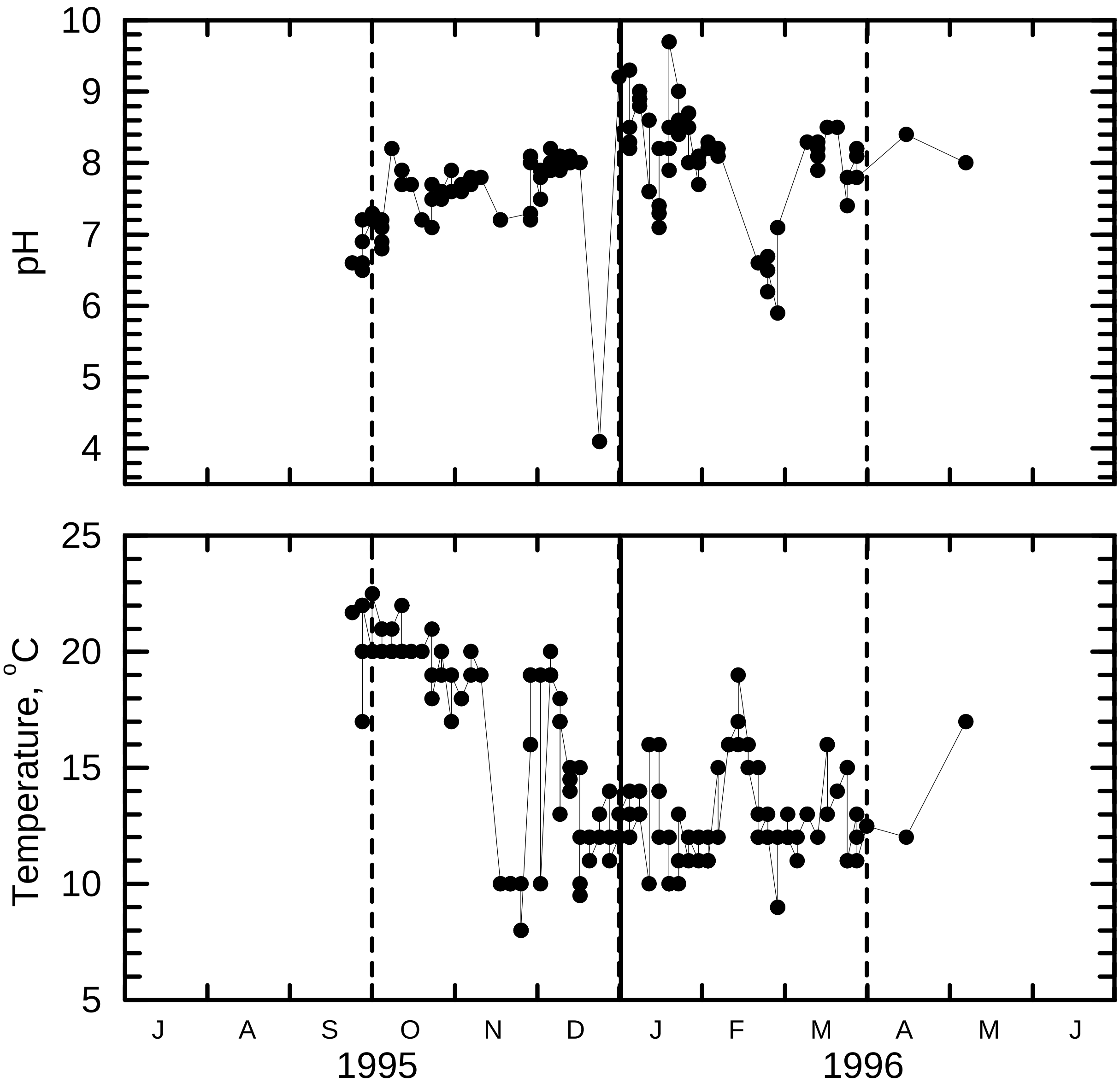
Figure HYD-A-1: GLOBE School in California, USA



Figur e HYD-A-2: GLOBE School in Califor nia, USA



Figur e HYD-A-3: GLOBE School in Califor nia, USA



Figur e HYD-A-4: GLOBE School in Florida, USA

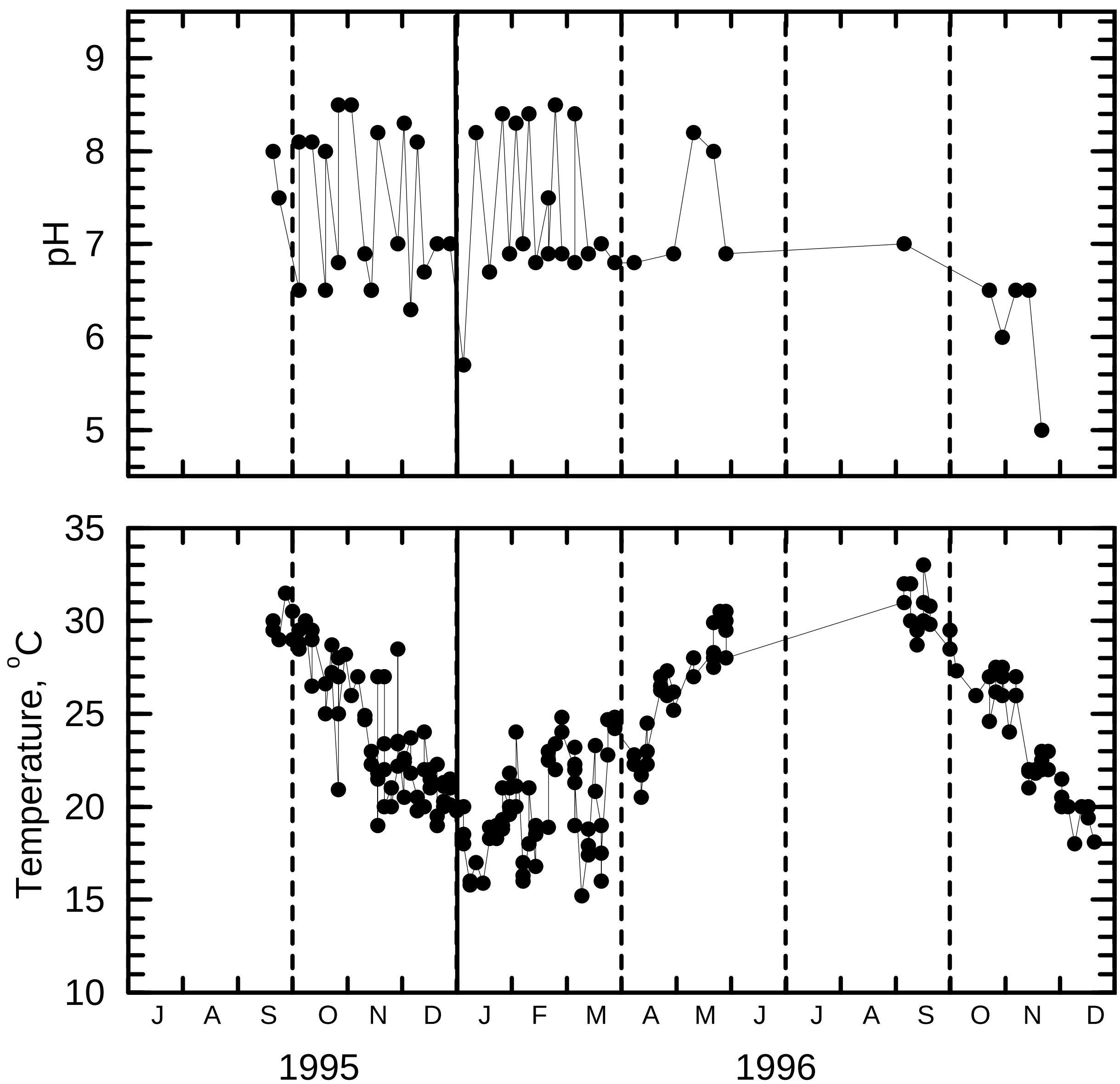


Figure HYD-A-5: GLOBE School in Washington, USA

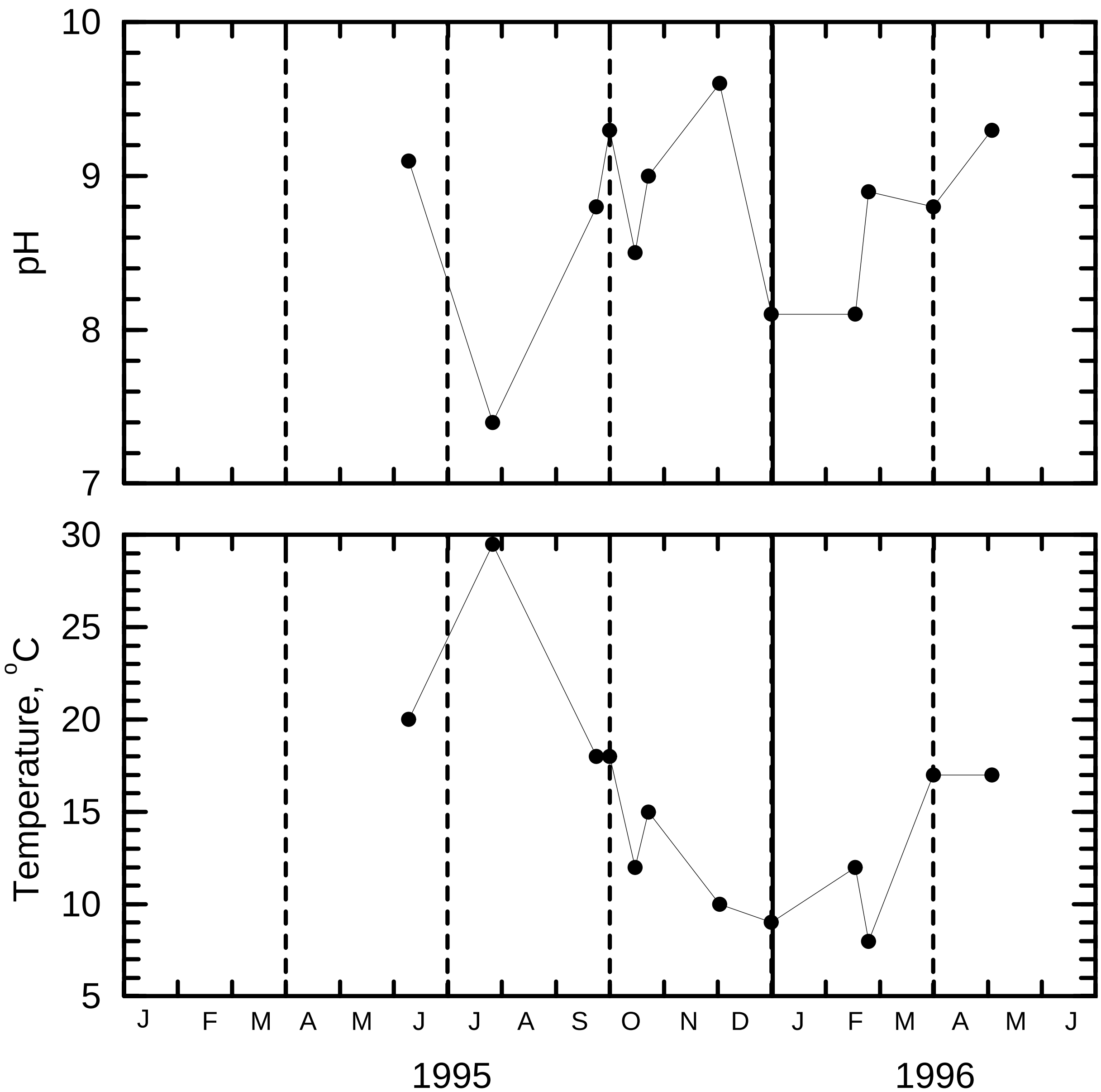
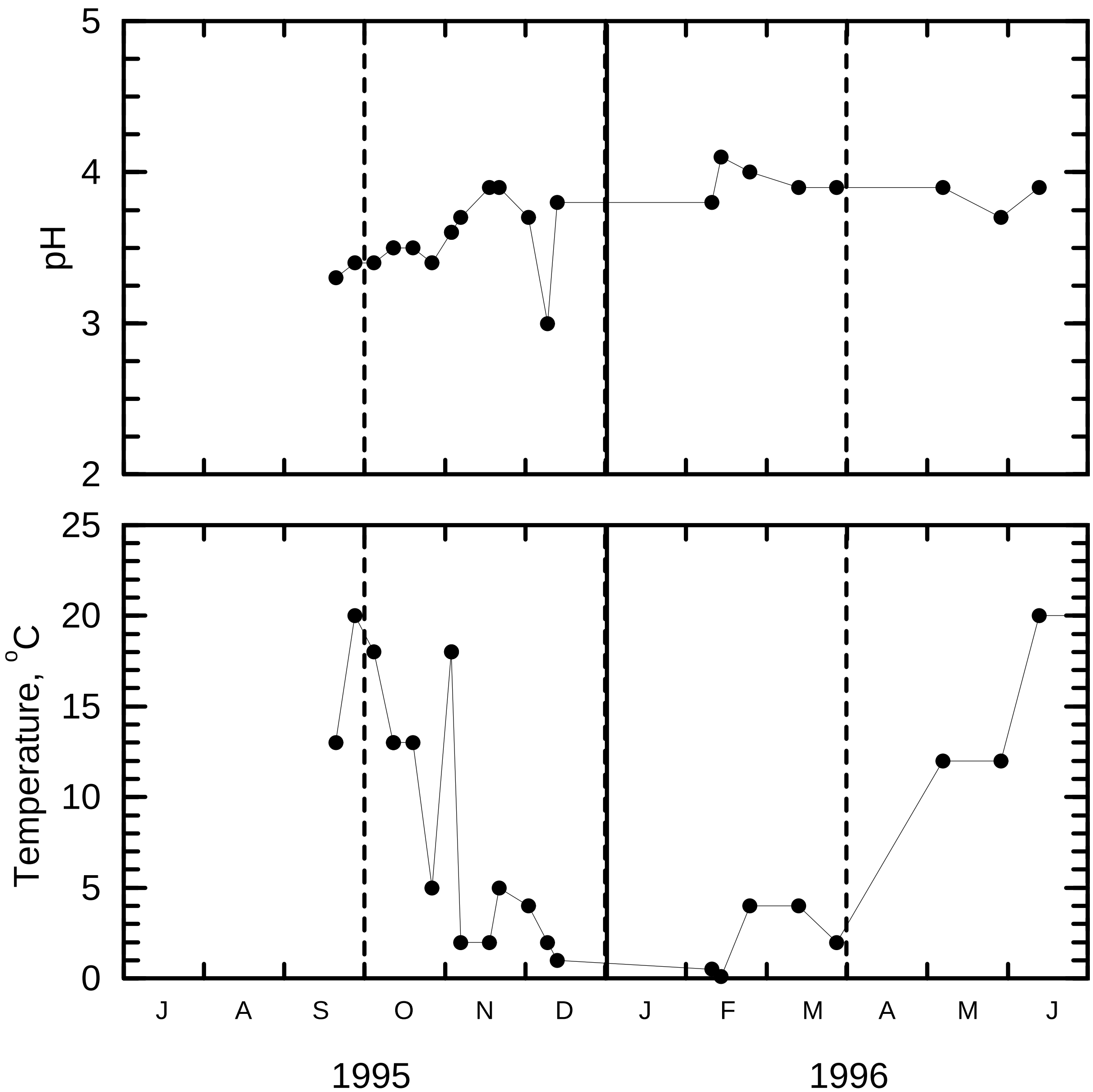
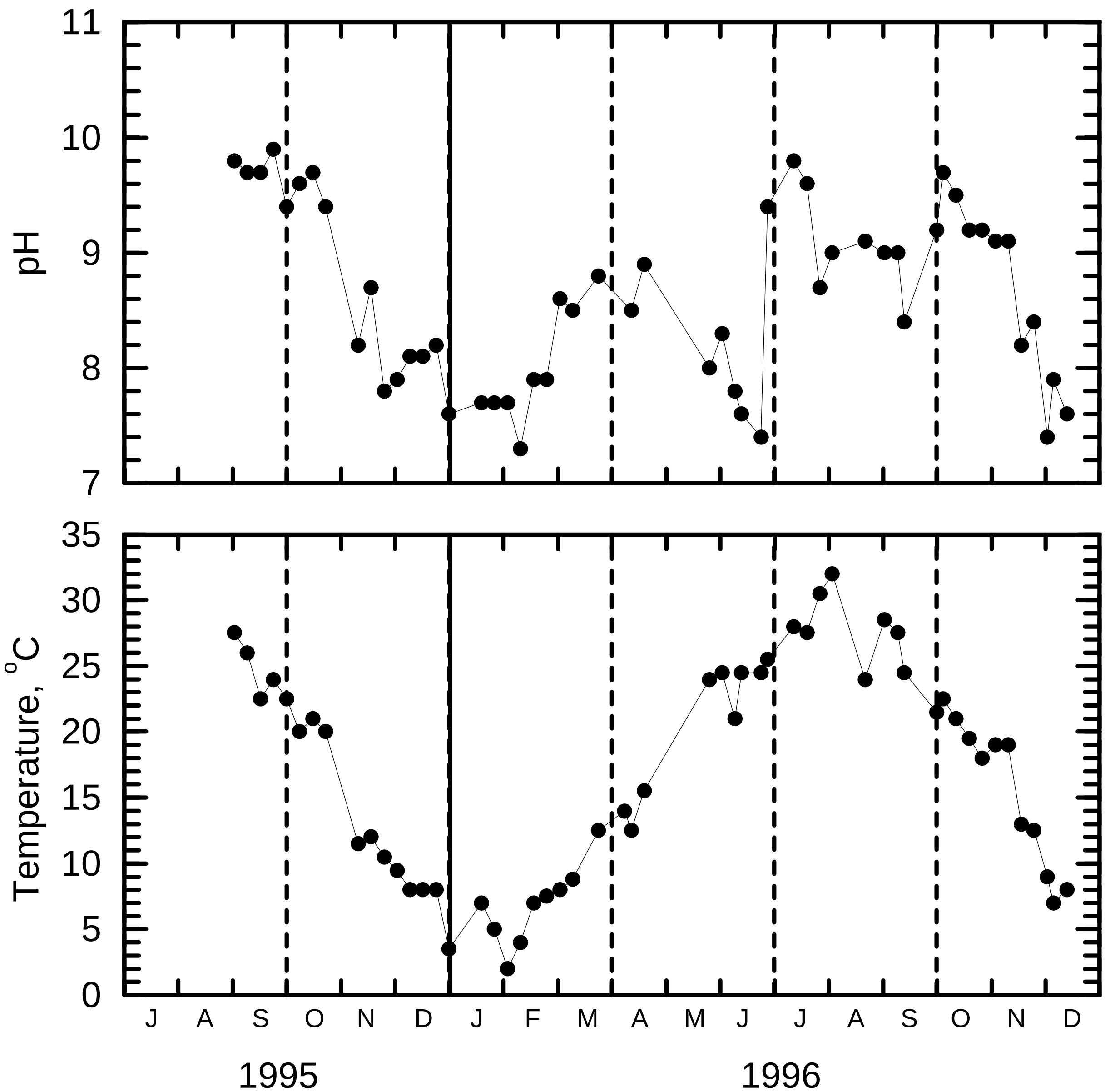


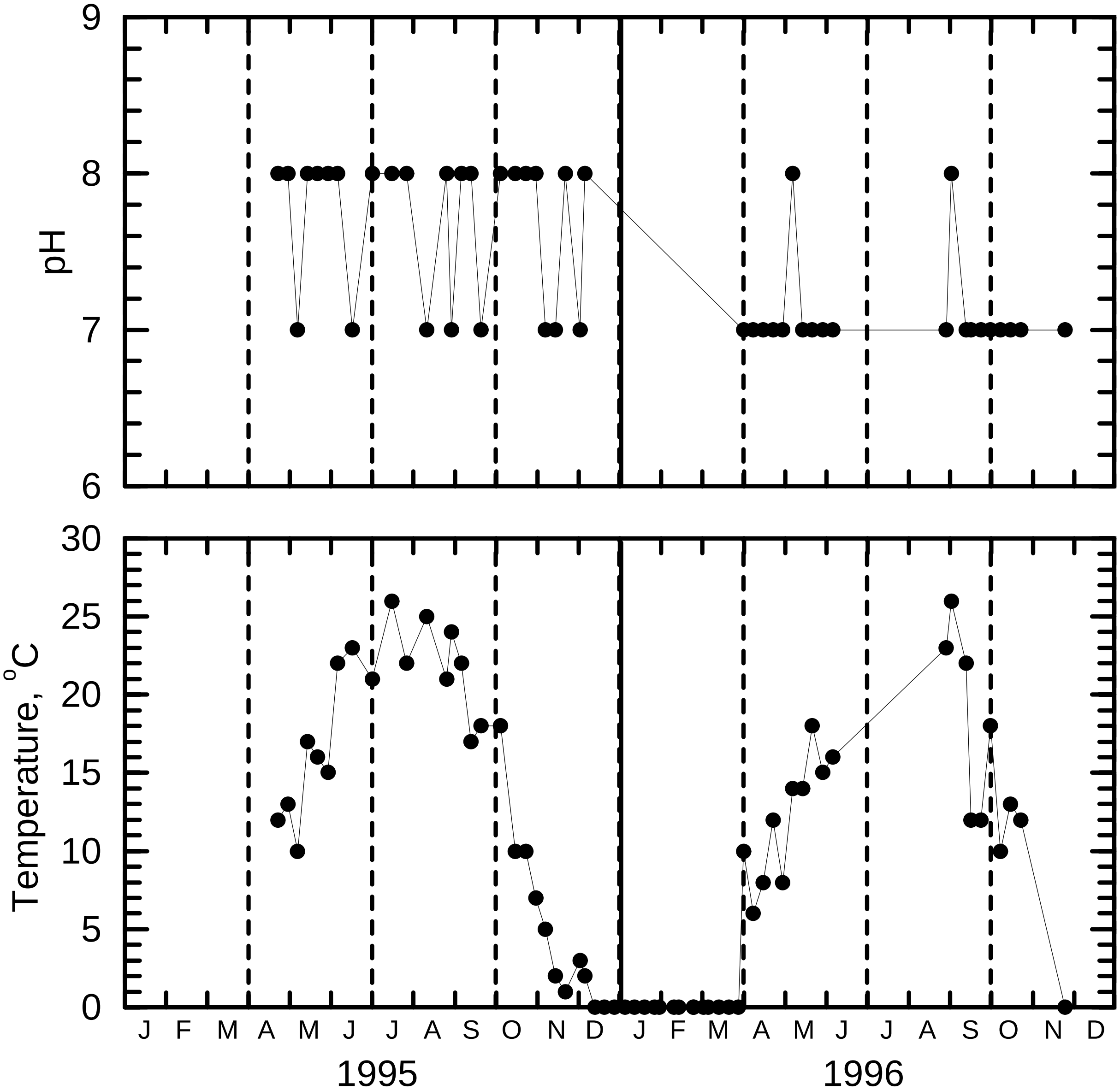
Figure HYD-A-7: GLOBE School in New Jersey, USA



Figur e HYD-A-8: GLOBE School in Japan



Figur e HYD-A-9: GLOBE School in the Midwest of the United States



Figur e HYD-A-10: GLOBE School in Califor nia, USA

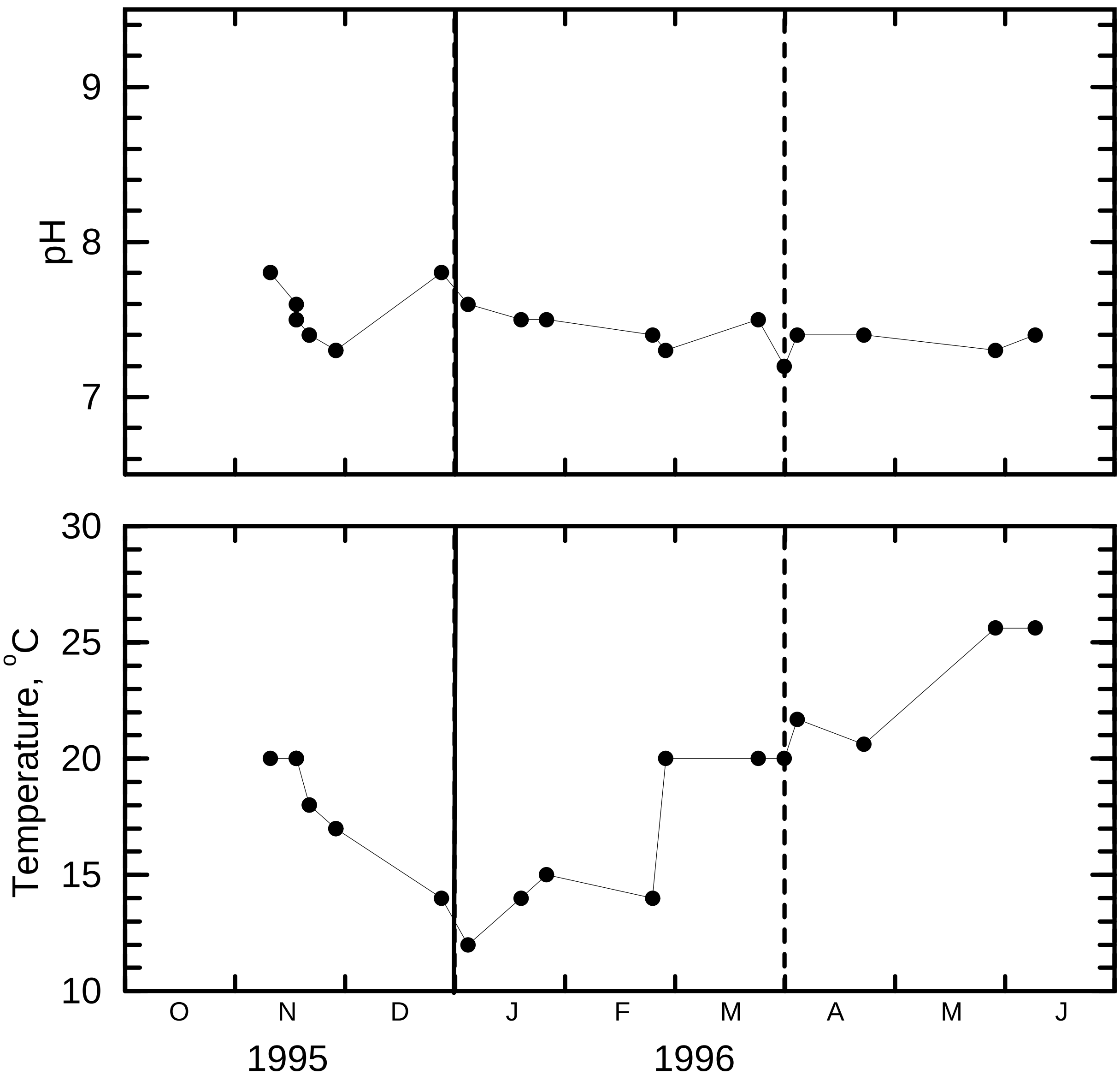
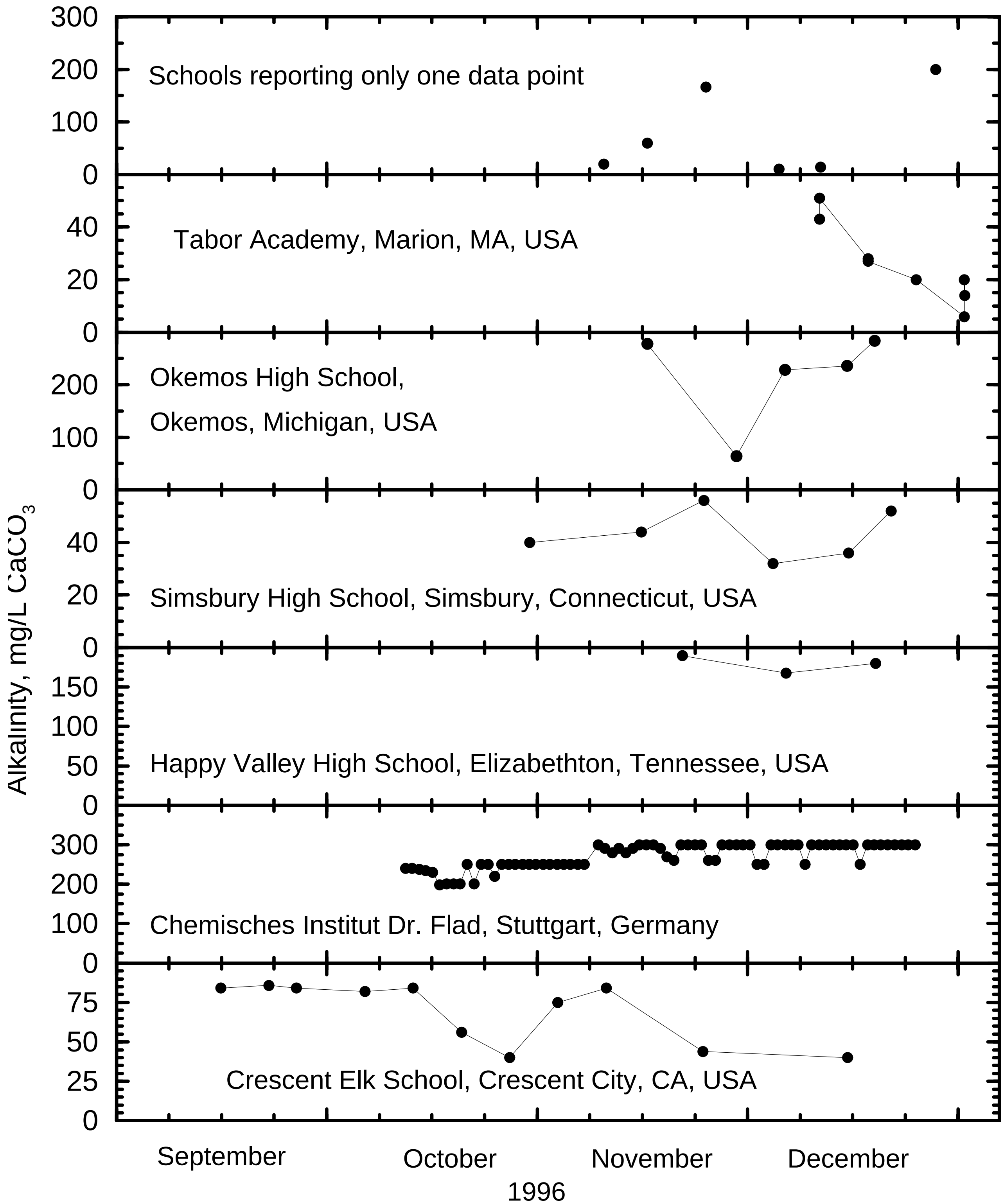


Figure HYD-A-11: GLOBE Alkalinity Data, September -December 1996



Figur e HYD-A-12: GLOBE Electrical Conductivity Data, September -December 1996

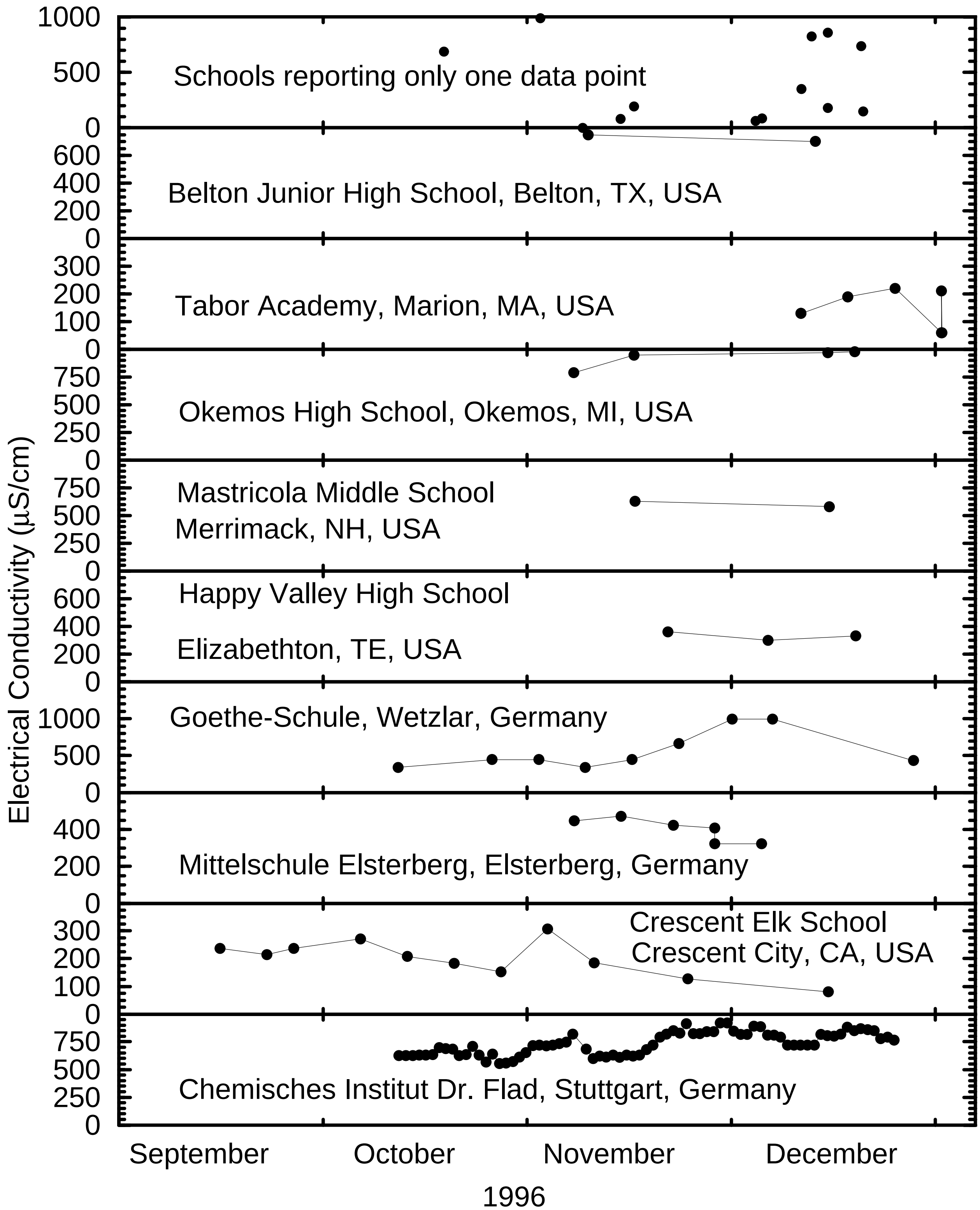
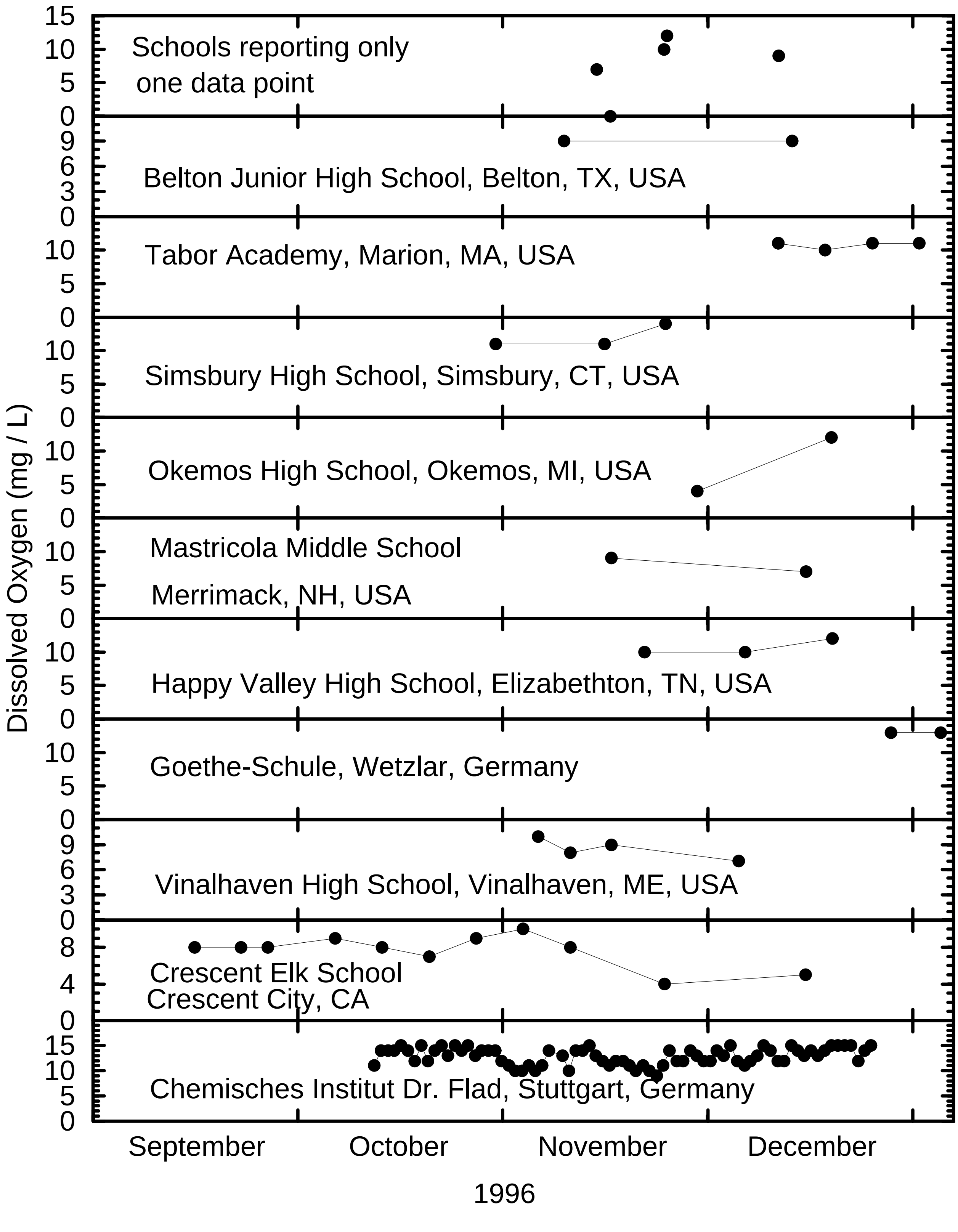
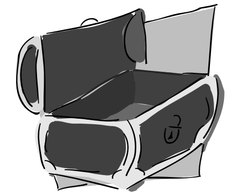


Figure HYD-A-13: GLOBE Dissolved Oxygen Data, September -December 1996



Glossary



accuracy
: The closeness of a measured value to a true value (See precision).

acid
: Any substance that can donate a hydrogen atom or proton (H^+) to any other substance.

acid rain
: Rain characterized by pH values below 6.

acidic
: Characterized by pH < 7.

acidity
: 1. The amount of strong base (e.g. Sodium Hydroxide) necessary to titrate a sample to a pH of around 10.3; measures the base neutralizing capacity of a water.
: 2. An acid quality or state. (Common Usage)

aerosols
: Liquid or solid particles dispersed or suspended in the air.

alkaline
: Characterized by pH > 7.

alkalinity
: The amount of strong acid (e.g. Hydrochloric Acid) necessary to titrate a sample to a pH of around 4.5. Measures the acid neutralizing capacity of a water and is often reprinted as ppm $CaCO_3$.

aqueous
: Containing or contained in water.

background concentration
: The level of chemicals present in a water due to natural processes rather than due to human contribution.

base
: Any substance that accepts a proton (H^+) from another substance.

benthic
: Pertaining to bottom dwelling water animals or plants.

brackish water
: Water containing dissolved salts at a concentration less than seawater, but greater than fresh water. The concentration of dissolved salts is usually in the range 1000 - 10,000 ppm.

buffer solution
: One that resists change in its pH when either hydroxide (OH^-) or protons (H^+) are added. The stable and known pH value of these solutions make them suitable for calibrating pH measuring devices.

calibration
: To set or check an instrument against an index or standard of known value through some type of proportional or statistical relationship.

chlorinity
: The chlorine concentration of a solution.

colorimetric method
: Many procedures for measuring dissolved substances depend on color determination. The underlying assumption is that the intensity of the color is proportional to the concentration of the dissolved substance in question.

conductivity
: The ability of an aqueous solution to carry an electrical current. Depends upon the concentration of dissolved salts (ions), the type of ions, and the temperature of the solution. Typical units are microSiemens/cm or micromhos/cm. (These are equivalent).

denitrification
: The act or process of reducing nitrate to ammonia. Nitrite may be an intermediate product.

density
: The ratio of the mass of a substance to its volume.

dissolved oxygen
: The mass of molecular oxygen dissolved in a volume of water. The solubility of oxygen is affected nonlinearly by temperature; more oxygen can be dissolved in cold water than in hot water. The solubility of oxygen in water is also affected by pressure and salinity; salinity reduces the solubility of oxygen in water.

dissolved solids
Solid particles that have become liquid by immersion or dispersion in a liquid (e.g. salts).

enrichment
Making a water more productive (e.g. by adding nutrients).

eutrophication
A high level of productivity in a water body, often due to an increased supply of nutrients.

evaporation (of water)
Change from liquid to vapor at a temperature below the boiling point.

hydrologic cycle
The series of stages through which water passes from the atmosphere to the earth and returns to the atmosphere. Includes condensation to form clouds, precipitation, accumulation in soil or bodies of water and re-evaporation.

hypothesis
A tentative statement made to test its logical or empirical consequences.

in situ
Situated in its original natural place. (Latin)

lentic
Relating to, or living in standing water (lakes, ponds or swamps).

logarithmic scale
A scale in which each unit increment represents a tenfold increase or decrease.

lotic
Relating to, or living in actively moving water (streams or rivers).

microSiemens/cm
Metric unit of measurement for conductivity. Equivalent to micromhos/cm.

Micromhos/cm
Standard unit of measurement for conductivity. Equivalent to microSiemens/cm.

molar
Unit of measurement for concentration (moles per liter of solution).

molecule
The smallest fundamental unit (usually a group of atoms) of a chemical compound that can take part in a chemical reaction.

natural waters
Systems that typically consist of the sediments/minerals and the atmosphere as well as the aqueous phase; they almost always involve a portion of the biosphere.

neutral
Characterized by pH = 7.

nitrate
A salt of nitric acid (HNO_3). Nitrates are often highly soluble and can be reduced to form nitrites or ammonia.

nitrate-nitrogen
Concentrations of nitrate (NO_3^-) are often expressed as mass of nitrogen per volume of water.

nitrite
A salt of nitrous acid (HNO_2). Nitrites are often highly soluble and can be oxidized to form nitrates or reduced to form ammonia.

nitrite-nitrogen
Concentrations of nitrite (NO_2^-) are often expressed as mass of nitrogen per volume of water.

pH
The negative logarithm of the molar concentration of protons (H^+) in solution.

photosynthesis
The process in which the energy of sunlight is used by organisms, esp. green plants to synthesize carbohydrates from carbon dioxide and water.

ppm
Usually parts per million. (Equivalent to milligrams per Liter in GLOBE calculations).

ppm chlorinity
By weight, equal to milligrams of chlorine per Liter, with the assumption that one Liter of water weighs one kilogram.

ppt

Usually parts per thousand. (Equivalent to grams per Liter in GLOBE calculations).

precipitation

1. The falling products of condensation in the atmosphere. e.g. rain, snow, hail

2. Separation in solid form from a solution due to chemical or physical change (e.g. adding a reagent or lowering the temperature).

precision

A measurement for the degree of agreement between multiple analyses of a sample (See accuracy).

productivity

The formation of organic matter averaged over a period of time such as a day or a year.

proton

A positively charged elementary particle found in all atomic nuclei. The positively charged hydrogen atom (H^+).

reagent

A substance used to cause a reaction, especially to detect another substance.

reduce

In chemical terms, to change from a higher to a lower oxidation state (i.e. gain electrons).

runoff

The component of precipitation that appears as water, flowing in a stream or river.

saline water

Water containing salt or salts.

salinity

A measure of the concentration of dissolved salts, mainly sodium chloride, in brackish and salty water.

salts

Ionic compounds which in water solution yield positive (excluding H^+) and negative (excluding OH^-) ions ; the most common of which is sodium chloride, or “table salt”.

saturated solution

A solution that contains the maximum amount of dissolved substances at a given temperature and pressure.

solubility

The relative capability of being dissolved.

solute

A substance that dissolves in another to form a solution.

solution

A homogeneous mixture containing two or more substances.

solvent

A substance that dissolves another to form a solution.

specific gravity

The ratio of the density of a substance to the density of water (at 25° C and 1 atmosphere).

standardization

To cause to conform to a standard.

standard

A measure with a value established through outside means for use in calibration; a known reference.

suboxic water

Very low levels of dissolved oxygen; denitrification occurs (nitrate is converted to ammonia).

suspended solids

Solid particles in a fluid that do not dissolve or settle out.

suspensions

A mixture in which very small particles of a solid remain suspended without dissolving.

tides

The periodic rise and fall of the waters of the ocean and its inlets, produced by the attraction of the moon and sun. Occurs about every 12 hours.

titrant

The reagent added in a titration.

titration

The process of ascertaining the quantity of a given constituent by addition of a liquid reagent of known strength, and measuring the volume of reagent necessary to convert the constituent through a given reaction.

topography
The surficial relief features of an area.

total dissolved solids
The total mass of solids remaining when a given volume of filtered water is evaporated to total dryness following an accepted protocol.

transparency
Having the property of transmitting rays of light through its substance so that bodies located behind can be distinctly seen.

turbid
Not clear, or transparent due to stirred up sediment.

water quality
A distinctive attribute or characteristic trait of water, described by physical, chemical, and biological properties.

watershed
1.A line of separation between waters flowing to different rivers, basins or seas.
2. A term to mean the area drained by a river or stream. (Common Usage.)

water vapor
Water in the gaseous phase.

Hydrology Investigation

Hydrology Study Site Data Entry Sheet

School Name

Measurement Time:
Year: [ ] **Month:** [Select] **Day:** [ ] **Hour:** [ ] **UT**
Current Time: 1997 June 18, 20 UT

Name of site: [ ]
Create a unique name that describes the location of your site.

Please supply as much of the following information as you can now. When you obtain additional information click on the Data Entry button and go to "Edit a Study Site".

Source of data: ○ **GPS** ○ **Other**

Latitude: [ ] deg [ ] min ○ **North** ○ **South** of the Equator
(Enter the data in the format 56 deg 12.84 min **and** mark whether it is North or South.)

Longitude: [ ] deg [ ] min ○ **East** ○ **West** of the Prime Meridian
(Enter the data in the format 102 deg 43.90 min **and** mark whether it is East or West.)

Elevation: [ ] meters

Classification of sampled water body

Water Type : ○ Salt ○ Fresh

Moving Water : ○ Stream ○ River ○ Other
Approximate Width of Moving Water [ ] meters

Standing Water : ○ Pond ○ Lake ○ Reservoir ○ Other

Size of Standing Water: ○ much smaller than 50m X 100m (football field) ○ roughly 50m X 100m (football field size) ○ much larger than 50m X 100m (football field)
If Known : Approximate Area of Standing Water [ ] km^2 Average Depth of Standing Water [ ] meters

Sample Location : ○ Outlet ○ Bank ○ Bridge ○ Boat ○ Inlet

Turbidity : ○ Clear ○ Turbid ○ Don't Know
Can you see the bottom? ○ Yes ○ No

Channel/Bank Material: ○ Soil ○ Rock ○ Concrete ○ Vegetated Bank

Bedrock: ○ Granite ○ Lime Stone ○ Volcanics ○ Mixed Sediments ○ Don't Know

Dissolved Oxygen Kit
Manufacturer : ○ LaMotte ○ Hach ○ Other

Model Name :

Alkalinity Kit

Manufacturer : LaMotte Hach Other

Model Name:

Conversion Constant :

Nitrate Kit

Manufacturer : LaMotte Hach Other

Model Name:

Salinity Titration Kit

Manufacturer : LaMotte Hach Other

Model Name:

NOAA/Forecast Systems Laboratory, Boulder,Colorado

US Training ID

Measurement Time:
Year: [ ] **Month:** [Select] **Day:** [ ] **Hour:** [ ] **UT**
Current Time: July 13, 1997, 16 UT

Study Site Location: [01Creek South of School]

Water Source: [Normal State]

* TRANSPARENCY

Cloud Cover: ○ Clear ○ Scattered ○ Broken ○ Overcast

Enter data below, depending on whether you used the Secchi Disk or the Turbidity Tube method.

First Secchi Disk Test:
Depth where disk disappears (m): [ ] Depth where disk reappears (m): [ ]
Distance Between Where Observer Marked Rope and Water Surface: [ ] meters
Second Secchi Disk Test:
Depth where disk disappears (m): [ ] Depth where disk reappears (m): [ ]
Distance Between Where Observer Marked Rope and Water Surface: [ ] meters
Third Secchi Disk Test:
Depth where disk disappears (m): [ ] Depth where disk reappears (m): [ ]
Distance Between Where Observer Marked Rope and Water Surface: [ ] meters

Turbidity Tube:

Note: If the pattern of the turbidity tube disappears before the tube is full, enter the depth where it visible, otherwise enter the length of the turbidity tube.
Test 1 (cm):[ ] Greater than depth of Turbidity Tube? ☐
Test 2 (cm):[ ] Greater than depth of Turbidity Tube? ☐
Test 3 (cm):[ ] Greater than depth of Turbidity Tube? ☐

WATER TEMPERATURE
Water Temperature: [ ] degrees Celsius

DISSOLVED OXYGEN
Average Dissolved Oxygen of water sample: [ ] mg/L (equivalent to ppm)

WATER PH
Average Water pH: [ ] **measured with** [Select]

CONDUCTIVITY
Average Conductivity of water sample: [ ] microSiemens/cm

* SALINITY
Location of Tide:
Name of Site: [ ]
Latitude: [ ] deg [ ] min ○ **North** ○ **South** of the Equator
(Enter the data in the format 56 deg 12.84 min **and** mark whether it is North or South.)

Time of High or Low Tide before Salinity Measurement (UT):
Hour: [ ] Minute: [ ] High Tide Low Tide
Time of High or Low Tide after Salinity Measurement (UT):
Hour: [ ] Minute: [ ] High Tide Low Tide

Enter data below, depending on whether you used the Hydrometer or the Titration method.

Hydrometer Method:
Temperature of water sample in 500mL tube (degrees C): [ ]
Specific Gravity of water sample: [ ]
Salinity of water sample: [ ] ppt
Average Salinity of water sample: [ ] ppt

Salinity Titration Method:
Salinity of water sample: [ ] ppt

ALKALINITY
Average Alkalinity of water sample: [ ] mg/L as $CaCO_3$

* **NITRATE**
Average Nitrate and Nitrite of water sample: [ ] mg/L nitrate nitrogen + nitrite nitrog
Average Nitrite of water sample: [ ] mg/L nitrite nitrogen

Comments:
[ ]

* These inputs are new as of June, 1997. Find out more.

NOAA/Forecast Systems Laboratory, Boulder,Colorado